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ABSTRACT

This publication, issued twice per year, includes proceedings from Two-Year College Chemistry Conferences and papers of special interest to the two-year college chemistry teacher. This issue contains discussions concerning the content of first-year, second-year, and other introductory courses in chemistry, such as special courses for nonscience and inhalation therapy students. Also discussed are the content and curriculum of chemical technology courses and special instructional methods in chemistry, such as computer-oriented laboratories and independent study. Special topics in both instrumentation and science and society are presented. The content of a short biochemistry course for teachers is described. (MH)

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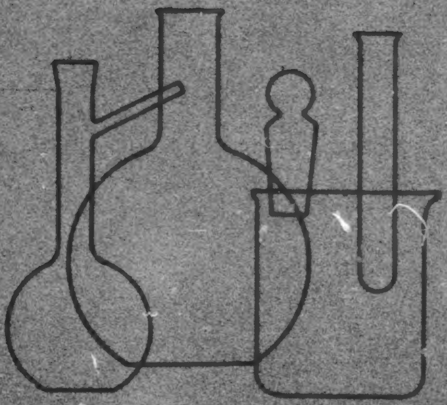

CHEMISTRY IN THE TWO-YEAR COLLEGE

1971 NO. 2

COMMITTEE ON CHEMISTRY IN THE TWO-YEAR COLLEGE
DIVISION OF CHEMICAL EDUCATION · AMERICAN CHEMICAL SOCIETY

SE 021 315

FOREWARD

This issue of *Chemistry in the Two-Year College* closes the 11th year of activity of the Division of Chemical Education, Inc. of the American Chemical Society presently being directed by the Committee on Chemistry in the Two-Year College.

During 1971 the Committee sponsored four Two-Year College Chemistry Conferences, published two issues of *Chemistry in the Two-Year College*, and studied the problems and programs of chemistry departments through ten subcommittees. The 1971 Committee includes 65 chemists from 65 institutions in 32 states and 4 Canadian provinces.

The 1971 issues of *Chemistry in the Two-Year College*, the four Conferences and the work of each subcommittee all strongly suggest that the chemistry programs of the 2-year colleges of the United States and Canada are in the midst of an era emphasizing innovation. Indications are that this inclination toward instructional innovation will increase in the next few years. Most innovations are concerned with the individualization of instruction, the increased utilization of instrumentation, or with the integration of chemistry in interdisciplinary programs.

The trend toward the individualization of instruction involves such developments as the use of learning specifications or behavioral objectives, the inclusion of programmed activities designed to assist students achieve the objectives. Self-pacing instructional programs and independent study programs are also finding a place in 2-year colleges.

The trend toward instrumentation includes 3 distinct types of hardware or instrumentation: computational instruments or systems; chemical or scientific instruments; and multi-media instrumentation. Many of the most pressing problems and some of the most significant innovations have to do with the educational applications of the instrumentation, the development of software to go with the hardware, and methods of acquiring such instruments.

The trend toward the integration of chemistry with other disciplines in interdisciplinary programs involves natural or integrated science courses, environmental science courses, experimental colleges and science in occupational curricula.

Chemistry in the Two-Year College is a sequel to the older *Proceedings of the Two-Year College Chemistry Conferences* which were published six times during the sixties. The first issue of *CTYC*, 1971, No. 1, was published in May and this is the second issue. The 1971 issues and subsequent volumes will feature papers and discussion summaries from the Conferences and other papers of special interest to the 2-year college chemistry teacher. These 96-page issues will feature sections devoted to general chemistry for science majors, second-year chemistry courses, chemistry for non-science majors and other introductory courses, chemical technology programs, instructional methods, teacher development, special topics and administration of chemistry programs. Although not all sections may be included in each issue, we intend to keep a balanced publication.

The Two-Year College Chemistry Conferences are 2-day meetings of chemistry faculty and administrators of the USA and Canadian community colleges, junior colleges, technical institutes, university branches or centers and post-secondary vocational-technical schools.

$2YC_3$ programs include Symposia on Special Topics in Chemical Education; Symposia on Innovations in the Teaching of Chemistry; keynote addresses and discussion sections for first-year science major chemistry courses; second-year chemistry courses; chemistry courses for non-science majors, occupational groups, and beginning students; chemical technology programs; and Timely Topic Forums on specific problems and programs. Exhibits of textbooks, models, instruments, charts, equipment, and filmed or taped media materials are also included.

The four 1971 Conferences at Catonsville Community College in Maryland, February; Los Angeles Trade-Technical College in California, March; Meramec Community College in Missouri, October; and San Antonio College in Texas, December, were typical of the geographical and chronological distribution of our Conferences but were the high points for program quality and attendance. The attendance totaled 694 for the 4 Conferences. All Conferences were attended by 155 or more, and Los Angeles, with 193, was the largest of the 28 conferences to date.

Findings, reports on progress, papers, and discussions from the following subcommittees will appear in future *CTYC* issues. The Recognition and Awards Subcommittee, chaired by Cecil Hammonds, Penn Valley Community College, works with the Committee on Educational Activities of the Manufacturing Chemists Association in recommending five finalists each year for the Annual MCA Two-Year College Chemistry Teaching Award, and in investigating additional ways in which recognition can be given outstanding individuals or collective achievements of the chemistry faculties of 2-year colleges. The Chemical Instrumentation for Two-Year Colleges Subcommittee, initiated in 1970, has developed phase 1 of an extensive study of chemical instrumentation in 2-year colleges. C. G. Vlassis, Keystone Junior College, is the Chairman. The Chemistry for Allied Health Programs Subcommittee, under the guidance of Ethelreda Laughlin, Cuyahoga Community College, has worked in developing programs involving chemistry for allied health courses; is evaluating the new ACS examination for these courses; and is developing a skeletal curriculum for the paramedical chemistry course.

The Behavioral Objectives for Two-Year College Chemistry Courses Subcommittee, headed by Wanda Sterner at Cerritos College, has attracted the largest attendance of any subcommittee, emphasizing the current interest in educational objectives. The group is evaluating input from these sessions to determine what programs, studies and publications are of greatest significance to faculty. In recent years many 2-year college chemistry faculty have become involved in the use of multi-media techniques. The Media for Two-Year College Chemistry Subcommittee, chaired by C. Herbert Bryce, Seattle Central Community College, was formed to identify significant media projects and papers; to organize Symposia showing the use of multi-media techniques; to encourage preparation of papers for *CTYC*; and to develop plans for use of multi-media techniques.

Kenneth Chapman of the ChemTeC Project first convened the Recruitment for Chemical Technology Subcommittee at the Chicago meeting. This group has since been identifying problems in recruiting chemical technology students and characterizing successful recruitment programs. The newly-formed High School Chemistry and Two-Year College Chemistry Interface Subcommittee, chaired by Curt Dhonau of Vincennes University Junior College, will study existing programs of cooperation between 2-year colleges and their feeder high schools and develop models for such cooperation. Louis Kotnik, Cuyahoga Community College, Metropolitan campus, directs the Subcommittee on Teaching Chemistry in the Urban Colleges in the identification and solution of their problems. The Publications Subcommittee has been working with the editor of the *Journal of Chemical Education* to develop a special section in the *Journal* for 2-year college faculty. Under Kenneth Chapman's leadership, the group will also assist in forming editorial policy for *CTYC* and the *2YC$_3$ Newsletter*. The Chemistry Booklist for Two-Year Colleges Subcommittee was inactive this year but should be reactivated next year when plans for revision of the 4- and 2-year college lists are accomplished.

Much work by many is necessary to accomplish as comprehensive a program as has been undertaken by the Committee this year. It is not possible to recognize all such persons here, but I would like to acknowledge the contributions made by Paul Santiago, Cecil Hammonds and John Mitchell, Chairmen of the Regional Conferences; C. G. Vlassis, Wanda Sterner, Catherine Travaglini and Nina Milton, Conference Editors; Katherine Weissman and William Wyatt, Conference Secretaries; Thomas Matey, Lawrence Dalen, Rudolph Heider and Charles Howard, Local Arrangements Chairmen; Kenneth Chapman, Committee Editor, and Robert Burham, Secretary; and to Margery Mooney, whose lovely sense of wifely duty causes her to contribute much time and effort to keep the 2YC$_3$ office operating.

The Committee wishes to acknowledge and express its appreciation for the financial and other support it has received from the Executive Committee of the Division of Chemical Education under the direction of Anna Harrison, Chairman. This sponsoring grant was augmented this year for the first time by 44 industrial commercial sponsors, 39 college sponsors, and over 100 individual subscribers to *Chemistry in the Two-Year College*. We invite all 2-year college chemistry departments to become sponsors, all faculty members and others interested to become subscribers, and all commercial and industrial organizations interested in chemistry in the 2-year college to become sponsors.

What does the future hold for 2-year college chemistry? Moving around the country to attend the four conferences, visiting two-year colleges and "talking shop" with chemistry faculties, and reviewing recent mail and current chemical education literature, I am led to believe that the 1972 and subsequent problems and programs of the 2-year college chemistry faculties will involve modules, mini-courses, models, education of the masses, man -- his health and environment -- and the search for money to implement innovation. We invite you to join us next year at a conference or as a subscriber to *Chemistry in the Two-Year College*.

William T. Mooney, Jr., Chairman

Erratum

The scope of the Two-Year College Chemistry Conferences and the wide variety of means by which material is collected for publication assures that errors will be made from time to time. We particularly regret the misplacing of credits for presented material. Thus, we wish to call your attention to an error in the 1968-1969 *Two-Year College Chemistry Conference Proceedings*, p. 24. William G. Daniel of Bluefield College, Bluefield, Virginia, should be credited with the article, "Chemistry Laboratories for the Future," instead of G. Tyler Miller of St. Andrews Presbyterian College, Laurinburg, North Carolina.

Kenneth Chapman, Editor

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FIRST YEAR COURSE CONTENT AND CURRICULUM

FUTURE TRENDS IN THE GENERAL CHEMISTRY COURSE

Wendell Slabaugh
Oregon State University, Corvallis, Oregon

Presented as the General Chemistry Section Keynote Speech,
26th Two-Year College Chemistry Conference, Los Angeles, March 27, 1971.

Some twenty years ago the General Chemistry course almost abruptly changed from an introduction to inorganic and descriptive chemistry to a principles-oriented course. During the next several years, more and more of what had been traditionally physical chemistry became part of the general course. Today, we are experiencing a shift toward the inclusion of the description of chemistry within the context of chemical principles. Pedagogically, the student can understand and use the principles better if there are more points of contact with the real world in terms of specific chemical phenomena. Furthermore, we have had to rediscover that students without sufficient mathematical background cannot adequately master some of the more advanced and quantitative aspects of chemical principles. It is anticipated that a more workable balance between descriptive and fundamental chemistry will be developed in the future.

In the past few years we have witnessed an awakened interest in the various media of instructional aids. In addition to the traditional projection systems, whole new systems such as television, the computer, and audio tapes, have come into the picture. All of these have been tested, tried, and many of them are being intensively used. But the results are not decisive. Somehow, after we invest much time and money in these newer systems or in the revival of an older system, we discover that the student is not necessarily "turned on," nor does it seem to favorably influence the enrollment in our chemistry courses. What do we try next?

More and more we are hearing of "hands-on" chemistry, the kind of chemistry the student experiences by performing a real-life experiment with his own hands, or in the classrooms, witnesses a live demonstration performed by his instructor. These activities seem to offer a refreshing alternative to instructional devices such as a fine motion picture or a precise computer printout of a reaction mechanism or such. The convenience of canned material vs the labor of preparing lecture demonstrations mitigates against the "hands-on" type of instruction. However, from the standpoint of student motivation and learning, there seems to be a renewed interest in the classical type of lecture demonstration. Here again, we may find an effective balance between the use of the more modern instructional media and the traditional, "first-person" demonstration experiment. After all, chemistry is blessed with more than its share of demonstrable topics, and we would be failing to achieve the most effective instruction if we did not exploit these opportunities.

Summary of Discussion Following Professor Slabaugh's Address

Summarized by J. Smith Decker
Phoenix College, Phoenix, Arizona

1. How do you develop good demonstrations?

Dr. Slabaugh responded: "A good method is to have a 3 x 5 card file in which you have demonstrations tabulated with equipment and chemicals listed on the card. For example, under sulfur you would have cards 1, 2, 3, 4, 5, etc., with the principle that is demonstrated by the demonstration and the equipment needed. The equipment should be assembled and left in ready condition such that it can be taken quickly from storage, demonstrated, and then returned again to storage."

2. Do demonstrations decrease drop-out rates? Do they really help to stimulate student learning, or is general chemistry just becoming too difficult for the average student?

The answers were as follows: (1) There are a number of students who get into the course who have not met the prerequisites of the course, which might be listed as: (a) some mathematical knowledge, (b) a desire to form good habits of study, and (c) a desire to spend the time to really learn. (2) Schedule the preparatory course and the engineering (general chemistry course) such that well-prepared students can go ahead according to their abilities and so that poorly prepared students can drop back and still achieve the goals they first desired.

3. Should we all teach the two types of courses: (1) for the major and (2) for the non-major type of course?

Dr. Slabaugh responded: "Which is the major and which is the non-major course? He cited the experience of Dr. Sears in Biology programs in which a course was set up for the non-major in biology and another for the major. Upon considerable experience they found that the non-major course developed into a better course for preparing majors than did the original program and that majors were going from this course into the majors. Therefore, the original course for biology majors was dropped in deference to the better course. One solution is to offer a variety of levels of instructions and to keep the students coming along to meet the levels and instruction you expect. The final comment was that there is a high correlation between a student's ability to do mathematics and his ability to be successful in chemistry.

4. What do we really mean by a general course for non-majors?

Many schools have introduced a course in appreciation of chemistry. At Phoenix College this is named Modern Aspects of Chemistry. It is a non-mathematical approach, and the instructors prepare their own materials both for the lectures as well as for the laboratory.

TRENDS IN SCIENCE MAJOR LECTURE COURSES

Gilbert P. Haight, Jr.
University of Illinois, Urbana, Illinois

Presented to the First-Year Science Majors Course Section,
22nd Two-Year College Chemistry Conference, Columbus, June 6, 1970.
Summarized by Florence Wolters, Western Campus, Cuyahoga Community College.

There is a need for a new type of general chemistry course. Besides presenting previously solved problems and newer problems to be solved, the course should deal with problems of the world. No longer should science remain isolated.

Two new courses, World I and World II, are in planning stages at the University of Illinois to meet the needs of present day students. The courses are being prepared by professors and students from a variety of areas, such as industrial engineering, chemistry, arts and political science.

An article entitled "Why are You in this Course?" from *Chemical Principles,* a new, general chemistry text by Dickerson, Gray and Haight, was distributed and discussed.

A science course for non-science majors was offered at the North Carolina State University, by Henry Bent. Students were graded on 6 out of 12 exams and the final exam. When asked their opinions, students thought that this was the first time that they were treated as adults and they "blew it."

Several problems of teaching chemistry to science majors were identified:

1. A tremendous expansion of knowledge.
2. The number of students vastly increased.
3. The upgrading of material in course. (This was justified by a few "eager, bright-eyed" students. The average student needs simple instruction and drill.)
4. The best scholars are not liked. Turns even B students off. Can't reach a student unless he likes you.
5. The courses go too fast. Too many topics are introduced.

Some topics taught in a major's chemistry course using titles based on the Westheimer Report are:

1. Structure
   (a) Electronic
   (b) Lewis
2. Dynamics
   (a) Thermodynamics
   Disliked by the average student. Shouldn't be given in the first term. Don't give an in-depth study to freshmen. Make definitions useful.
   (b) Equilibrium

(c) Kinetics

"On the run" data from the lab confuses students. The student quickly loses knowledge of this, due to lack of use.

Some recommendations were made:

1. Try to use connecting threads (spiral threads) in courses to reinforce material. For example, stoichiometry is repeated in: formulae, equations, electrode reactions, equilibrium, and solutions.
2. Use slides to present material in condensed form. (Examples - Electronegativity vs at no. and conductivity vs at no.)

IMPLEMENTING AN INSTRUMENTATION APPROACH TO THE FRESHMAN CHEMISTRY LABORATORY PROGRAM

William G. Daniel
Bluefield College, Bluefield, Virginia

Presented to the First-Year Science Majors Chemistry Course Section,
25th Two-Year College Chemistry Conference, Catonsville, February 6, 1971.

Commencing with 1968-69 I changed my freshman laboratory from the standard classical type, that is, where a group of students come into the laboratory and all do the same experiment to a new method. I now have fourteen stations, each complete with all the equipment and chemicals necessary for that experiment. By using these stations, I am able to let all the students perform experiments that otherwise couldn't be done easily using the old, classical approach. For instance, the Gas Phase Chromatography experiment couldn't be done using the classical method because of the expense involved. An experiment requiring the use of the Corning pH meter would not be practical for a small college under the classical laboratory system, since every student would require a meter.

The students are divided into groups of two and three. Therefore, each group has a different experiment during the same laboratory period. The groups are numbered and a list of all the experiments corresponding to each group is placed on a bulletin board accessible to all. The student can tell in advance what experiment he or she will perform each week.

We use no laboratory book. At each station there are directions and information which will be helpful for that particular experiment. Many of the experiments are written up "open ended" so that the student can perform the experiment as long as time and motivation persist. The experiments are as follows: (five types), Titration of Acids and Bases, The Spectronic 20, Analysis for Chloride, Heats of Reactions, Gas Phase Chromatography, Distillation, Electrolysis, Titration Curves by pH meter, Finding Molecular Weights (b.p. and f.p.), The Temperature Dependence of a Solubility Equilibrium, Crystallization and Microscopic Work, Synthesis of Magnesium Oxide, and Oxygen in Air. The students are given two demonstrations: Cottrell smoke precipitator and a method for obtaining the combining weight of zinc. These demonstrations work out well because we have a Fall recess and a Thanksgiving recess which cut off the laboratory period for the latter part of those weeks. By doing demonstrations we not only use good teaching aids, but are also able to combine laboratories during a free period in the first part of the week and prevent the classes from being separated.

The laboratories are scheduled for three hours each on Mondays and Thursdays; however, they usually run four hours instead of three. I have two laboratory assistants for each laboratory period. I monitor four experiments closely while each of the assistants have five experiments. During the first fifteen minutes of each laboratory period we go over the experiment with the group. After this we try to ask questions and stimulate thinking on the part of the members in the group. After an experiment has been completed, the group returns to the classroom and writes a report on the experiment for that day's work along with their data and answers to their unknowns if applicable. Then the group has a conference with the instructor and are asked questions to see if the members of the group have a proper understanding of the experiment in question.

What are the visible results from such a laboratory program as outlined above? I find that students teach each other very well. They seem to really enjoy laboratory work rather than viewing it as a necessary evil. Over half the students come to laboratory early in order to study the experiment, and almost everyone comes during the week to study their next week's experiment. Then too, I see much more independent work in the laboratory by this station approach. The students take pride in writing up their lab reports. From time to time I see students bring library books on the experiment that they are to perform that day. Many become so interested in the experiment that the allotted time soon passes by without their being aware of it. On several occasions groups have come back to continue the experiment further than they were able to do during the laboratory period.

One of the changes which I made earlier was to rearrange the experiments. For example, all experiments that involve weighing should follow the experiment on balances.

I am very encouraged and enthusiastic about this program.

INCLUDING QUANTITATIVE ANALYSIS IN GENERAL CHEMISTRY

R. Nelson Smith
Pomona College, Pomona, California

Presented as the First-Year Science Major Chemistry Keynote Speech,
20th Two-Year College Chemistry Conference, Fullerton, October 4, 1969.

I think that anybody would agree that upgrading of the high school chemistry certainly indicates some kind of a change in the freshman chemistry at the college level. I think there is another squeeze from the other side, that is the upper end, and it is in two forms. One is the pressure of time needed to put into other things. Also, there is a natural tendency to include analytical instrumentation and an analytical approach in chemistry courses at all levels.

First, let me say that the ACS Committee on Professional Training does not demand that I or anybody else do what I recommend this morning. I'm on that committee, so I feel sensitive about this one point. In my mind, qualitative analysis is not too applicable these days to industrial problems or to much of research at any level. I think there is a great difficulty in teaching all of the equilibrium principles that you need for quantitative analysis and, after that, all of the chemistry you need to have to go along with qual. In other words, I think that teaching qual is harder than teaching quant. I think it's a lot harder for the students because it's a double dose. You can do a cookbook deal but, from the learning process, I think it's harder.

I also believe there is a general utility, for a major fraction of all the students who take freshman chemistry, of approaching the laboratory from the standpoint of simple instrumentation and quantitative methods and techniques. A large fraction of that class will be pre-med, zoology majors, lab techs, etc., certainly other than chemistry majors. These people will probably find more use for analytical and quantitative methods and techniques than they would for the qualitative.

There is also great difficulty in giving meaningful laboratory work related to lectures when initial emphasis is on atomic and molecular structure. I don't know what people do in the lab that's related to discussion in the lecture, at least at the freshman level. There is a simplification that can be attained in course scheduling by doing what I am recommending, that is, that there be a one-year freshman course, a one-year sophomore organic course (organic-analytical) and a third-year physical course. These are three core courses. Along with the physical you could then combine courses of interest to the interdisciplinary student or provide the straight chemistry program that different schools have. This simplifies the concurrent taking of math, physics, language and other requirements that are usually needed to go along with the chemistry program. It seems to me that for junior colleges there would be a simplification in transfer if they had to include a full year of organic. I know that there are many arguments going along these lines.

There are problems in giving a freshman course that integrates quantitative analysis: lecture organizations, equipment problems, philosophy of experimentation. For the lab to be meaningful, the related *principles* must be discussed previously or concurrently, at the worst, in the lecture; otherwise, it's only a black box type of laboratory, so you've missed the boat. You must get to equilibrium principles early in the course. This is the key point. It takes about six weeks to get to this point. You start out talking about units, instruments and reliability of measurements, including probability, distribution, standard deviation, etc., for the reliability. Then I would summarize the composition of matter - no great detail. Names and formulae, stoichiometry and concept of mole, that sort of thing. Properties of solution, but not colligative properties, and concentrations. Gases: gas laws and vapor pressure. Weight-volume relations. Energy (thermochemistry type of energy) by way of the calorimeter. Specific heat, entropy of transition, standard entropy of reaction and formation. Then combine the energy concept with volume of gases; then to kinetic energies of molecules, distributions and velocities, reversibility of reactions, activation energy for reaction, relationship between the equilibrium constant and entropy of the reaction, general development of equilibrium law from kinetic considerations. When you reach this point -- building on this and amplifying it in the course -- you can do a whole variety of things. Meaningful discussions are possible: precipitation, purity of a precipitate; the analytical applications, K_{sp} problems; combine analytical and qualitative analysis; complex ions, electron transfer; quantitative aspects, balancing oxidation, reduction equations. Here is where you would take up free energy. Colligative properties. Nine weeks doing this sort of thing after equilibrium laws are learned. Structure is not mentioned yet.

The second semester is taken up by half with a detailed discussion of atomic, molecular, crystal structure. We have energy from first semester to build on. The other half of this semester includes problems of synthesis, chemical kinetics and mechanisms, organic chemistry and nuclear. This is a very crude outline.

Problems in the lab -- one crucial thing is efficiency of student time. Don't waste students' time. For example, we give pre-dried, cooled and desiccator unknowns which they can pick up in the lab. We have drying oven schedules and ovens with circulating air. One oven can be used for 20 minutes. By using a series of ovens you have rapid drying and saving of time. Teflon stopclocks save time. There is no such thing as under- or over-greasing. Consecutive time is important. We operate on one lab/week - four hours; 1 - 5 pm. This is more useful than 2 two-hour labs. One of the most important points is expectation of results. I visited a mid-western college and talked to students who "bitched" about their course. The level of expectation was completely unreasonable. They had to do an experiment as many times as it took to get results, too much time was spent, and they hated the course. Freshmen do not have a lot of experience and perfection comes only by experience. Concurrent scheduling of experiments is necessary, especially with a large number of students and expensive equipment. You don't have to have a gigantic investment in equipment. We have handled 130 students with 6 pH meters, 4 calorimeters, 6 colorimeters, 3 gas chromatography units and 4 geiger counters. We have stations for things like desiccators. For example, if you have a lab section of 25, you need only 25 desiccators. If they must keep samples in desiccators, you can have a couple of desiccators for the retention of samples of everybody.

TOPICAL OUTLINE FOR GENERAL CHEMISTRY
FOR SCIENCE MAJORS

Subcommittee on General Chemistry
Curriculum Committee, Division of Chemical Education, Inc.
American Chemical Society
Brock Spencer, Chairman
Beloit College, Beloit, Wisconsin

Prepared as part of the Topical Outlines Project of
the Curriculum Committee, April 1971.

The following Topical Outline for General Chemistry is intended to be an outline of topics commonly taught in a first-year general chemistry course at most colleges and universities, and is not intended to specify either a specific order for covering the topics, a necessarily preferred system of classification for all of chemistry, or the range of "relevant" applications which may be appropriate to illustrate a particular topic. Thus, for example, thermodynamics may precede or follow molecular structure and bonding in a particular course; it may or may not include a molecular interpretation of the thermodynamic processes, and may be illustrated by examples from biochemistry, geochemistry, environmental science, space science, industry or cosmology. Although this Topical Outline is intended to be the basis for constructing behavioral objectives for general chemistry, we recognize that the behavioral objectives initially will be limited primarily to recall and quantitative reasoning for the concepts covered. At this time we are not attempting to include other types of objectives which are obviously part of any course, nor are we anticipating extensive use of methods other than question-answer-calculation for demonstrating mastery of the behavioral objectives.

1. Atomic and Kinetic-Molecular Theory of Matter
   A. Atoms, elements, compounds, symbols
   B. Gas laws - ideal and real gases
   C. Kinetic-molecular interpretation of gases - distributions, heat capacities
   D. Liquids - properties and kinetic-molecular interpretation solutions
   E. Solids - crystal structures and thermal properties
2. Stoichiometry
   A. Molecular stoichiometry - atomic and molecular weights
   B. Reaction stoichiometry - mass and volume relations in chemical reactions
   C. Solution stoichiometry - concentrations
3. Thermodynamics
   A. Definitions - system, state
   B. First Law - energy, work, heat
   C. Thermochemistry - heat capacities, enthalpy, Hess's Law
   D. Second Law - criteria for spontaneous change - entropy, free energy
   E. Temperature dependence of thermodynamic state functions
   F. Colligative properties
4. Equilibrium
   A. Phase equilibria
   B. LeChatelier's Principle
   C. Equilibrium constants and equilibrium calculations
      (1) Phase equilibria
      (2) Homogeneous gas equilibria
      (3) Solution equilibria - acid base, redox, solubility, complexes
5. Kinetics and Mechanism
   A. Empirical rate laws, radioactive decay
   B. Elementary reactions and reaction mechanisms, nuclear reactions
   C. Collision and activated complex theories
   D. Temperature effects on reaction rates
   E. Catalysis, enzymes
6. Structure of Atoms
   A. Nuclear structure
   B. Bohr theory of the hydrogen atom
   C. Quantum theory of the hydrogen atom and many-electron atoms
   D. Periodic properties of elements related to electronic structure
7. Molecules and Chemical Bonding
   A. Ionic bonding
   B. Covalent bonding - directed valence, molecular orbitals, electron pair repulsion, multiple bonds, aromaticity
   C. Molecular geometry, bond polarity, electronegativity
   D. Stereochemistry

8. Structure and Reactivity
    A. Functional groups
    B. Acid-base theories - Bronsted, Lewis, Hard/Soft or other modern theories
    C. Metals and non-metals - periodic properties
    D. Oxidation-reduction
    E. Medium effects
    F. Transition metals and coordination compounds

FUTURE TRENDS IN FRESHMAN COLLEGE CHEMISTRY

Charles E. Mortimer
Muhlenberg College, Allentown, Pennsylvania

Presented at the First Year Chemistry Section at the 25th Two-Year College Chemistry Conference, Baltimore, February 6, 1971.

The future of chemistry and instruction in chemistry depends not only upon internal influences, the developments within the science itself, but also upon external influences, which spring from the culture and society in which the science exists. At the present time, external influences appear to be of paramount importance.

The science of an age is an integral part of the culture of the age; the art, literature, social institutions, economy, religion, values, and science all reflect the spirit of the age. Historians have compared the present period with the renaissance, and the similarities are striking. Both are periods of great change that may be characterized partly by: a questioning of values, the development of new art forms, the emergence of new types of living patterns, the establishment of new educational institutions, daring exploration, a growing secularism and skepticism, religious upheaval, development of technical expertise, a burgeoning growth (relative to the times) of knowledge and information, and an increased emphasis on the individual.

History does not repeat itself but one wonders whether the ultimate changes to our culture deriving from the present period will be as deep seated as the changes resulting from the renaissance. One thing is certain, we are now engaged in a search for new values, and we appear to be "zeroing in" on the individual, on social consciousness, and on humanity itself. And this occurs at a time when the study of science has been, in some ways, radically "dehumanized." I believe that all academic disciplines, not only chemistry and the sciences, are going to become more centered on man.

Dr. Donald F. Hornig, in his address to the Snowmass Conference on Education in Chemistry, describes the factors which led to a "golden age" of chemistry and the pressures that, in the late 1960's have resulted in a retreat from this high point. Declines in the job market, research subsidy, and the proportion of students entering studies leading to careers in science, have occurred and probably will continue.*

What does all this add up to with respect to future trends in freshman college chemistry? I believe that freshman chemistry must, and will, become more human centered. Science, in general, appears to be "turning students off." They are concerned about social action and want studies directed toward the improvement of the human condition. The introductory chemistry that they meet is a cold, demanding, abstract rigorous monster to which they do not wish to apprentice themselves.

Chemistry was not always this way. The teacher of introductory chemistry in the past spent time in demonstrating the relevance of the discipline to the needs of man and society, and we must return to this practice. Perhaps the emphasis should be slightly different—less directed to the importance of chemistry to industry and more centered on the ways chemistry helps to meet the more fundamental needs of man.

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*Hornig, D. F., *J. Chem. Ed.*, 48, 30 (1971)

We must communicate the worth of our subject not only in practical terms but also as an intellectual adventure. We should demonstrate that science is as creative as art or music and that the conepts of chemistry are the work of the mind of man and are changeable. A science student should be in a position to appreciate the close connection between science and philosophy.

Some of the post-sputnik innovations in teaching must be reevaluated. In the past decade, the quality of instruction in high school and college has been raised by an impressive degree. For good students and strongly motivated students, the accelerated and enriched programs have proven to be very successful. For average students, however, our programs may have made unrealistic demands. Furthermore, the programs have failed to attract a higher proportion of students to the study of chemistry. I believe that we must become more realistic in respect to the needs, abilities, and level of maturity of our students, and I think that there will be a modification in the trend toward ever increasing rigor and sophistication.

In addition, the trend toward an increasing emphasis on theory to the neglect of descriptive chemistry will probably be reversed. The descriptive aspects of chemistry are an important part of the science; an introductory course is incomplete without some coverage of them. Furthermore, theory itself is of meaning and value only insofar as it interprets descriptive fact.

Lastly, it is necessary that instruction in chemistry utilize techniques to handle the ever increasing amount of chemical information. In addition to programmed instruction and the other new instructional aids, several techniques used in other disciplines seem appropriate. Paradigmatic teaching involves the thorough study of an aspect of the subject in order that the student can independently apply what he has learned in the study of the model, or paradigm, to similar problems. Furthermore, in the past instructors in chemistry have made little use of outside reading assignments and independent study.

THE ONE-SEMESTER CHEMISTRY COURSE FOR ENGINEERS

Jean Scurlock
Longview Community College
Kansas City, Missouri

Presented at the First Year Chemistry Section at the 24th Two-Year College Chemistry Conference, New Orleans, December 8, 1970.

Some years ago, the engineering schools took a survey of engineers to find out which of their college courses they considered to be most useful and which the least useful. Unfortunately for us, chemistry did not fare very well in these surveys. So when the engineering schools decided to trim the number of hours which an engineer needed for graduation, chemistry was considered a prime target. However, happily for us, we did not get the ax, only the hatchet.

The Chemistry Department of Metropolitan Junior College was informed of the results of the survey 4 or 5 years ago. However, nothing further occurred until we received the following memorandum from the University of Missouri-Columbia dated February 20, 1969, on the subject, "Transfer of Credit to the College of Engineering." This memorandum contained the following statements:

> "Beginning September, 1969, the College of Engineering will initiate a new and completely restructured 126 hour curriculum in all fields of engineering. This is a reduction of ten hours from our old program... Transfer credit cannot be given for some college level courses which may have necessarily been taken but are not listed in our curriculum for credit towards an engineering degree. Examples of this would be:
> 1. Trigonometry and college algebra
> 2. Introductory Chemistry–a one semester general education terminal type course. Not part of a beginning sequence designed for engineers of majors in physical science.

3. Introductory physics—a one semester general education terminal type course. Not part of a beginning sequence designed for engineers of majors in physical science.
4. The first course in freshman English I cannot be counted in a 126 hour program. A second course in freshman English will transfer into engineering as credit for English 60, Exposition."

In other words, the reduction in total hours by 10 is to be accomplished by assuming that the students entering college are better prepared than was formerly the case. Since Introductory Physics and Chemistry courses were never given credit even previously, the major changes were in Math and English were the student is expected to be able to start his math with calculus and his English with second semester English. Most of our students begin with calculus, but English is another story, so even our best students will at the outset, have three credit hours that are non-transferrable.

Then came the blockbuster for the Chemistry Department:

> "Also effective, September 1969 (this memorandum was dated October 20, 1969) we recommend, except for Chemical Engineering, that no student take more than one basic beginning professional level course in freshman chemistry."

On October 23 and 24, members of our engineering department visited the Columbia and Rolla campuses and returned with the information that a special five credit-hour chemistry course for engineers had been introduced at Columbia and I quote: "Their course, Chemistry 5, usually taken after the first semester concurrently with calculus, does not have a chemistry prerequisite." The information from Rolla was: (and I quote) "The Calculus-Analytical Geometry sequence has been reduced to 14 hours, Chemistry to a *single four hour course* for most engineers and Physics to two four hour courses.

Before I continue, I would like to touch on other matters, not the subject of this paper, but also of concern to us. At Columbia, chemical engineers take the regular 10 hours of General Chemistry but Rolla follows the Engineering Chemistry 4-hour Quantitative Analysis course in the sophomore year. (Columbia does not require Quantitative Analysis as such.) Eight hours of Organic Chemistry are then given at Rolla in the junior year while Columbia offers six hours in the sophomore year. Since our General Chemistry sequence is 9 hours, the transfer student will be one credit hour short at Columbia and one credit long for Rolla. We have made accomodation in Quantitative Analysis for variable credit, all the way from 3 to 5. Chemistry majors need either 4 or 5 credits, Chemical Engineers at Columbia need 4 and our Pharmacy students need 3. All these students get two lectures a week; the rest of the credit hinges upon the number and types of experiments required, i.e. 1, 2 or 3 labs per week. We may have to do something similar for Organic Chemistry since the requirements now range from 10 for majors to 6 for Columbia and we certainly do not have enough students to offer three separate courses.

The crisis for the Chemistry Department came in the middle of the fall semester (1969) when the Chemistry Department was informed of the developments at Columbia and Rolla. Our students learned of this event at about the same time and suddenly came to the realization that only five hours of the then required 9-hour Chemistry sequence for graduation at Longview would transfer. I immediately wrote letters to the Engineering Deparments of Missouri-Rolla and University of Missouri-Columbia informing them that we would conform to the new requirements and requesting that for one year only, they accept our Chemistry 111 (the first course in our major sequence) as satisfying the Chemistry requirement for the 1969–70 year only. I stressed the fact of non-communication in the planning stage, making it impossible for us to have converted the same year that they converted. They eventually conceded to my request. In the meanwhile, I informed the students that Chemistry 111 would transfer to satisfy the Chemistry requirement for engineers but stressed the fact that the student would be deficient in chemical knowledge and advised them to take Chemistry 112 anyway if they wished to be as well prepared as their counterparts at Columbia and Rolla. After examining the list of subjects to be covered at Columbia and upon being pressed by my students, I had to admit, that the only subjects in which they would be deficient would be Thermodynamics, Chemical Kinetics, Chemical Equilibrium, Radioactivity and Organic Chemistry (the latter they would not get anyway as it is not covered in our Chemistry 112). Since these subject matters constitute roughly about one-half of the subjects covered in Chemistry 112 and knowing that Thermodynamic and Kinetics in general are covered in some of their other courses, I was hard put to insist, even weakly, that they should take 112, though selfishly, I knew full well what this would do to my Chemistry 112 enrollment. (As it turned, students who felt they needed to get more chemical knowledge simply enrolled in Chemistry 115, the Engineering Course, instead of the second semester General Chemistry 112.)

The University of Missouri-Columbia uses Mortimer for its text, Schaum for its problem book and Frantz and Malm for the laboratory. Probably the easiest way for me to show you how UM-C solved its problem of teaching two semester of chemistry in one is to show you what was covered and what was left out.

University of Missouri-Columbia

Mortimer	*1969-70*	*Fall 1970*
1. Introduction; Units; Math		
2. Atomic Structure		
3. Chemical Bonding and Nomenclature		
4. Chemical Equations and Quantitative Relationships		
5. Gases		
6. Liquids and Solids		
7. Oxygen and Hydrogen	omit	omit
8. Solutions		
9. Electrochemistry	omit	
10. Nonmetals	omit	omit
11. Chemical Thermodynamics		
12. Chemical Kinetics and Chemical Equilibrium		
13. Acids and Bases	omit	omit
14. Ionic Equilibrium	omit	
15. Metals		omit
16. Complex Compounds	omit	omit
17. Organic Chemistry		
18. Nuclear Chemistry		

The Laboratory Experiments used were the same each year.

University of Missouri – Columbia

Laboratory *Frantz and Malm*

Exp. 1: Weighing Operations and Gravimetric Techniques
10: Group Relationships in the Periodic Table
11: Ionic and Covalent Compounds: Ionic Reactions
2: Chemical Separation of a Mixture

Laboratory *Frantz and Malm*

Exp. 4: Formula of a Compound from Experimental Data
7: Gas Analysis Based on Molar Volume
23: Molecular Weight by Freezing Point Depression
24: Thermochemistry
25: Rate of Chemical Reactions
26: Reversible Reactions and Chemical Equilibrium
17: Chromium and Manganese
34: The Silver Group
---: Organic Chemistry (Mineographed Notes)
---: Check out and assembly of molecular models

Exerpts from the letter I received from John Guyon concerning the success of their course at UM–C are:

a) We have about 150-200 students per semester.
b) The course is judged to be moderately successful.
  1) Morale and attitude of students is not good -- they appear to consider the course a necessary evil.
  2) Primarily due to lack of a textbook designed for chemistry for engineers, the material probably does not seem relevant to the students.
c) 85% of those who complete the course receive passing grades.

At Longview, the decision was made to divide the engineering students in half and teach Chemistry 115 both semesters. This meant that I would get students fresh from high school. We made a study of our regular Chemistry students for the Fall of 1969.

Statistics	*Chem 111, Fall 1969*		
47 students enrolled	C or better	66%	(31)
	D or better	77%	(36)

- 2 students were improperly enrolled without either High School Chemistry or Preparatory Chemistry 107; one received a W and the other a C–.
- 9 students had taken Chemistry 107
  9 passed (5 B's, 4 C's) 100% success

Math Preparation

- 18 students with Calculus (or concurrent enrollment)
  16 students with C or better, 1 C, 1 W 89% C or better
- 16 students with D or W (no F's)
  10 enrolled in College Algebra and/or Trigonometry 63%
  2 not enrolled in any math course (and without calculus)

SECOND YEAR COURSE CONTENT AND CURRICULUM

FUTURE TRENDS IN THE SOPHOMORE YEAR ORGANIC CHEMISTRY COURSE

Robert T .Morrison
Morristown, New Jersey

Presented as the Second-Year Chemistry Course Keynote Speech, 26th Two-Year College Chemistry Conference, Los Angeles, March 27, 1971. (Also at the 23rd Conference, Chicago, September 12, 1970 and the 19th Conference, New York City, September 6, 1969.)

The lecture system for teaching college chemistry should be abolished. It is out of date and teaching can be done better by other methods. In a lecture-type class, a teacher comes with old notes. The students try to write down everything that the teacher says or writes on the board. The teacher effectively prevents questions from students by lecturing sufficiently fast to prevent such an interruption. Textbooks are not used in most classes today because the teachers tell students what they must know and what they do not need to know. This system of teaching evolved when there were not enough books for each student. Now, books are the cheapest thing in the student's budget.

If learning is to take place, information must be transmitted. This can be done by the lecture system or by the Guttenburg method–Bound Optimally Organized Knowledge–B.O.O.K. In the Guttenburg method, the initial transmission of knowledge is in the student's room from a well-organized, clearly printed textbook. Then the classroom becomes an opportunity for discussion, corrections and questions. It is inefficient for a teacher to stand up and read old notes which students transcibe poorly. It is far better to use the teacher as a resource person to help the student.

There are some objections to this approach. In some advanced classes a teacher may know more than any text. If this is the case he should make use of mimeographed notes. Textbooks may go out of date, but good ones do this slowly and it gives the teacher a chance to bring his students up to date. A teacher must find a textbook that thinks like he does. If he cannot find such a textbook, he may have to write his own text. Some feel that a lecture is stimulating; but the spoken word is not an efficient way to teach. Class size may be a problem, however, the Gutenberg method has been successfully used in classes up to 120 students.

Summary of discussion in New York Second-Year Chemistry Section Following Professor Morrison's Address (Summarized by Mary Guy, Santa Fe Junior College, Gainesville, Fla., Recorder).

Professor Donald Scott of Drew University presented a brief critique of Professor Morrison's talk. He agreed with Professor Morrison's concepts and "trends" in organic chemistry, but emphasized the problem of determining trends based on a small sampling of friends and colleagues. If there is a trend, it is to get away from the straight lecture, but the problem lies in involving the class. Professor Scott suggested that a biannual publication of new and pertinent questions in organic chemistry be made available.

A question and answer period followed with Professor Morrison providing most of the answers.

1 . **How can we get students to read material before lectures ?**

It is largely a matter of study habits already developed. The professor must insist on it and good students will comply, poor students may not. A concerned professor can work with the faculty who teach the prerequisite chemistry courses and with school counselors to help develop good study habits.

2 . **We are concerned about poor students who pick up minor points and miss the important points .**

Emphasize the important points by the assignment of problems which utilize those points.

3 . **How can one make students do the problems ?**

The Socratic method should be used. Get the class to solve the problems.

4. Does the arrangement of the room affect student involvement?

Anything that makes the group more intimate is better. The students and the teacher should be closer physically and on a more equal basis.

5. The teacher has the responsibility of emphasizing what is important. Morrison & Boyd's text stifles teacher individualism.

Supplementary notes are necessary but texts remove the tedium of organizing and presenting everything.

6. Please make a comment on organic laboratory.

It is a problem to keep the laboratory work behind the material in a conventional lab. New approaches and laboratory texts are being developed. A professor at NYU says that Fieser's lab manual is the only one which teaches technique, the main purpose of laboratory. Only when more good teachers are available will labs be more diversified and improved.

7. How far do you go in your textbooks?

Everyone on the faculty goes to carboxylic acids, then each picks areas he wishes to emphasize. There is too much in the text because of a lack of time available when writing the revision. We are trying to write a smaller book with the same sequence for the second edition.

8. Are we handicapping students by using one text over another?

Don't worry about it. If the student has been trained to be autonomous, disciplined and responsible about study habits, use of references, etc., he won't have any problem on transferring.

Summary of Discussion in Chicago Second-Year Chemistry Section
Following Professor Morrison's Address

1. What is your basic teaching methodology?

Abolish the lecture during which students just copy anyway. Prune unessentials away from the course. Teach well, what you do teach. I may also present antifacts to stimulate thought There is no point in starting a project unless the project is done right.

2. What is your approach to the content of the course?

The fundamentals come first. Optional chapters follow primarily for good students and what we do, we do well.

3. What new topics are to appear in the new edition of Morrison & Boyd?

Spectra–conformational analysis, carbenes, acids, orbital symmetry (photo-chemistry), and biochemistry.

4. What do you feel should be in lab?

There are several new lab manuals. Use one that tends to bring the student closer to the reality of situations in real life.

5. Some students are not sure if the course will transfer from a Junior College. How do you feel about the content?

A terminal student would profit with an organic course, but primarily organic is for the student who is going on; therefore, the two-year colleges should do what the four-year colleges are doing.

6. The book is accepted so well, one might feel ill at ease throwing out material in the text. Do you have an outline of essentials?

One can't really say; it depends on the class. A person could cut material within a chapter. The new third edition is cut down in size with optional chapters. One would have to use his own discretion according to his class.

7. How can one abolish lecture? What mechanics would be used?

First, assign reading material ahead of class. Secondly, get the students to ask questions. The lecturer can then pick difficult parts and explain them in depth. This should be followed by working a problem.

8. **How do you handle questions from "nuts"?**
One can deliberately not see his hand during class. Talk to him after class.

THE USE OF SPECTRA IN THE SECOND-YEAR COLLEGE CHEMISTRY COURSE

Irving Glover
Oak Ridge Associated Universities

Presented as the Second Year Chemistry Course Keynote Speech, 24th Two-Year College Chemistry Conference, New Orleans, December 5, 1970.

The classical methods of qualitative organic analysis (boiling points, melting points, qualitative tests for elements, chemical tests for functional groups, formation of derivatives, mixed melting points) are excellent devices for teaching basic concepts in organic chemistry and laboratory skills. Modern methods of analysis, however, have dwarfed the classical methods in research and industrial applications. For example, 40 years were required for the structure elucidation of the hemin molecule by the classical methods while modern techniques provided structure elucidation and synthesis of the complex molecule reserpine in less than 4 years.

It may not be feasible or even desirable in the second year college chemistry course to provide the elaborate and expensive equipment required to obtain spectra of organic compounds. On the other hand, it is becoming increasingly easier to obtain and present the *results* of spectroscopic analyses. Spectra and spectral data are readily available from such sources as the Varian catalogs (NMR)[1], Electronic Spectral Data[2], and the Sadtler Collection (IR, UV, NMR)[3]. There is a wealth of self-teaching materials such as the texts with instructional problem sets (R. Silverstein and G. Bassler[4], K. Nakanishi[5], and R. H. Bible[6]) and work books (A. R. Gennaro[7]). Infrared, ultraviolet, nuclear magnetic resonance and mass spectra can serve as useful teaching tools to supplement both lecture and laboratory in organic chemistry. Furthermore, their use can be integrated into the second year course without establishing a new unit of study concerning spectroscopic methods *per se*.

If spectra are to supplement lecture material, then spectral interpretation should follow naturally with the development of the organic course. The time to note that saturated C–H absorbs near 2900 cm^{-1} in the infrared is with the topic of alkanes, while intense ultraviolet absorption should be discussed in conjunction with conjugated double bonds and aromatic compounds.

Consider the following example of the use of spectra to supplement the topic "Arenes." The popular text by Morrison and Boyd[8] describes the identification of isomeric xylenes by the classical method of oxidation to the corresponding acids and differentiations on the basis of the melting points of the acids.

The power and limitations of spectroscopic techniques are well illustrated at this point. Comparison of the infrared spectra of the xylenes (Ref. 5, p. 126) provides an unequivocal choice between the isomers without the necessity of oxidation to the corresponding acids. It should also be noted that no clean-cut distinction can be made on the basis of nuclear magnetic resonance or ultraviolet spectra (cf. Refs. 1 and 2). The situation presents an excellent time for a brief discussion of the infrared absorption patterns of *ortho, meta,* and *para* disubstituted benzene derivatives.[9]

Spectra and spectral data for compounds studied and synthesized in the laboratory can be posted in the laboratory or on the chemistry bulletin board with accompanying discussion, questions and references. Discussion of the spectra may be required on the laboratory report or might be an optional part of the laboratory program.

The popular laboratory experiments[10] concerning the nitration of benzene, the preparation of aniline by reduction of nitrobenzene, and a study of the properties of aniline provide an example of how to make use of infrared, ultraviolet and nuclear magnetic resonance spectra in the laboratory. The ultraviolet data[4] in Table 1 show the wavelength shift and enhancement of intensity produced by chromophoric substitution (NO_2 group) on the benzene ring, the corresponding shifts and enhancement by auxochromic substitution (NH_2 group), and repression of the auxochromic effect when the nonbonding electrons are not able to interact with the π-electrons of the benzene ring (NH_3^+ group).

Table I

Compound	E-Band		B-Band		R-Band	
	λmax	(ϵ)	λmax	(ϵ)	λmax	(ϵ)
Benzene	198	(8,000)	255			
Nitrobenzene	252*	(10,000)	280	(1,000)	330	(125)
Aniline	230	(8,600)	280	(1,430)		
Anilinium cation	203	(7,500)	254	(160)		

*Called K-Band for chromophoric substitution.

Comparison of the infrared spectra[3,7] shows the persistence of typical phenyl absorption (3100 – 3000 cm^{-1} and 1600 – 1500 cm^{-1}), characteristic absorption of the NO_2 group (1515 and 1350 cm^{-1}) and the NH_2 group (3500 – 3200 cm^{-1}). Using the *o*-methyl derivative of aniline further illustrates aliphatic C–H (2900 cm^{-1}) and *o*-disubstitution of benzene (750 cm^{-1}).

The nuclear magnetic resonance spectra[1,3] clearly show the downfield chemical shift of the aromatic protons due to substitution by the NO_2 group, and the upfield chemical shift of the same protons due to the NH_2 group.

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THE ANALYTICAL APPROACH FOR THE ORGANIC LABORATORY EXPERIENCE IN THE SOPHOMORE YEAR—INSTRUMENTAL METHODS, OR . . . ANALYSIS IS BETTER THAN SYNTHESIS

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Presented to the Second-Year Chemistry Course Section, 20th Two-Year College Chemistry Conference, Fullerton, October 4, 1969.

Organic chemistry ought to be a second year course. The laboratory program should be developed so that there is an integration of spectroscopy, both qualitative and quantitative aspects of organic chemistry, and synthesis. At El Camino College we have a one-semester organic short course and a one-year organic chemistry course similar to a course at USC which we call Chemistry 7A, 7B. For analytical chemistry we offer Chemistry 5A, 5B. Second-year students at El Camino take Chemistry 7A, B and if they so desire they may take 5A, 5B concurrently. Chemistry 5A is gravimetric and volumetric analysis and 5B is instrumental methods. We also have Chemistry 3A, an introductory chemistry course. This is for students who do not pass our rigorous chemistry placement test for general chemistry. From Chemistry 3A students can branch into either our general chemistry (1A, B) or they can go into 3B.

The textbook we use in Chemistry 3B is Conrow, which is deductive organic chemistry. In 7A, B we use Morrison and Boyd. In the laboratory we use Boord and Bossart for some of the experiments and for theoretical aspects we use Robertson and Jacobs and a multitude of handouts which I have prepared and collected from various sources.

In the 3B program we have three hours of lecture and three hourse of laboratory a week. In our 7A, B program we have three hours of lecture, one hour of discussion or pre-lab and five hours of laboratory a week. We have two hours of laboratory one day and three hours on another day. Although it is too difficult to program at this time, I think that if the students could stand it, the five hours of laboratory would be even more valuable if we could put it in a block because so much more could be accomplished.

Articulation of 7A, B with four-year colleges is important. First, students are your best advertisements. If they transfer and do well in upper division programs, there is no problem with articulation. We have had no problems with articulation. It is up to the Dean of our division as the head of our department to contact various people at the state colleges and universities to make sure that our course is acceptable. The single problem that we did have with a state college vanished after one of our students spent a year there. The head of that department said, "Frankly, you are doing better than we are for our own students." I mention this because it is very important. One of the things which has been invaluable is the feedback information I receive from my former students. They often come back and tell me how they are doing, how they measure up and what they are lacking that other students may have. You ought to get to know your students so that when they finish your course they will give feedback information to you. We have had feedback from the following institutions: Los Angeles State, Long Beach State, Fresno State, UCLA, UC at Santa Barbara, UC at San Diego, Stanford, the University of Illinois and University of Southern California.

In addition to developing a rapport with your students, I recommend you become acquainted with someone at each of the four-year institutions to which your students go. One faculty member will introduce you to other faculty members who will get to know you and your program. When you want something like a couple of mass spectra, they can be most helpful in getting them for you. I now have actual mass spectra that I can use to project and use as teaching aids.

Next, don't be afraid to experiment. We should get away from the idea that in the laboratory every experiment works. When the student gets into upper division or graduate school, not every experiment works. Nine out of ten experiments may be failures; one success out of ten tries may be a very good ratio. I agree with the man who said that students often learn much more through an experiment that is a failure. Explain why it is a failure. When you are talking about controversy in modern organic chemistry, the possibility of side reactions, conditions that are not always the same or very difficult to duplicate, a student who has the idea that everything is going to be beautiful and successful in an organic laboratory has been mislead.

What ought to be in the laboratory?

1. The attempt to teach elementary techniques. This must be taught regardless of whether we are talking about one semester of lab for three hours a week, two semesters of two labs a week, or one lab a week for a year. We must teach students elementary techniques. At times we lose sight of the fact that the student coming into organic chemistry is encountering an entirely new area. He has never before experienced the types of techniques that he has to use in laboratory. You cannot provide a demonstration and expect him to go into the laboratory and follow suit. You have to be there; you have to demonstrate again; and then if necessary you must go out and hold his hand and show him how to hold the separatory funnel correctly. We spend about five weeks on elementary techniques. We prepare them for doing the types of experiments I want the 7A, B students to do. Teaching techniques is ideal for the way that Morrison and Boyd is written. In 7A I tell the students that while we are getting them oriented in the lecture part of the course to what's coming, we will also get them oriented in the lab. There is no coordination now between the lecture and the lab. We also do this in 3B.

2. Both 7A, B and 3B take up chromatography. The difference is that in 7A, B we have more time—we can do column chromatography, thin layer chromatography and paper chromatography. The ideal experiment at this point uses green leaf pigments, something students are familiar with. In addition, you can have every student in the class bring a green leaf because if you have twenty-eight students, you'll get twenty-eight different columns or TLC's and different separations. If you do this in 3B the lab time is almost gone.

3. Next, we do some spectroscopy. By this time the students are far enough along in 3B lecture to have covered the functional groups that are necessary for your IR and the different types of protons that are necessary for NMR. You are ready to talk about elementary concepts of spectroscopy even in 3B. We do the same in 7A, B only in more depth.

How do we handle spectroscopy? First, we use some CHEM Study films which are excellent for an introduction at this point. For example, we use "The Vibration of Molecules," "The Shapes and Polarity of Molecules" and "Molecular Spectroscopy."

Dr. Donald Hicks, Georgia State University, has a record called "Molecules-A-Go-Go." So I stand up in lecture one day and say, "Who in here knows all of the modern dances?" I pick out a couple and say, "All right, I want to see you in my office." I then play "Molecules-A-Go-Go" for them. There is an accompanying brochure which describes all of the necessary vibrational, translational and rotational motions they should do with their body and arms to do the dance. They practice and then demonstrate these motions for the class. This may look funny but it works. When they get done they understand scissoring, for example, which they didn't understand before. They know what the molecules are doing and when you talk about IR they know what you are talking about. It isn't some distant concept.

4. At the very end of 3B the students do a couple of syntheses. When the student completes 3B, he knows the techniques that he will encounter in a lab; he knows something about spectroscopy; and he can do a synthesis if he has to.

What do we have in 7A, B in the way of spectroscopy? We are fortunate at El Camino in that we have a UV and an IR and the students use them. We don't just demonstrate them. We also use the overhead projector to show spectra to the students. You cannot skip over this area lightly since every chapter or every functional group discussion in a book like Morrison and Boyd has spectra. I also recommend the *Spectra Workbook* developed by Sadtler Laboratories. They have three volumes. The third one is the best. They also provide a key. These spectra volumes provide plenty of problems. There are 110 compounds for which they give you the UV, IR and the NMR data and spectra. During one semester you can assign 25 of these compounds. You don't have to worry about the student copying. If he copies, he is the one that loses. He can't do it on an hour exam.

Students are tested. For tests I either take spectra out of one of the other workbooks and have it copied and stapled to the exam for interpretation or I make out worksheets giving them the data, so they learn how to interpret spectra.

When I talk about spectroscopy, I integrate the lab and the lecture. Students tell me that it is one of the most valuable parts of the course; they really understand.

As far as the electronics of the instruments are concerned, we go no deeper than the electronics that are given in Silverstein and Bassler, *The Spectrometric Identification of Organic Compounds.* I tell the students, "My lectures are based on Silverstein and Bassler and there are 10 extra copies in the library on reserve. If you don't understand me, go over and read the book. you still don't understand it, come see me." You should also have in your library for students to review, copies of Dyer, *Applications of Absorption Spectroscopy,* and Nakanishi, *Practical Infrared Spectroscopy.* Nakanishi is written from a practical standpoint for someone who knows very little about IR and seems to give the students the most problems. It also has spectra in it for the students to work with and gives the answers to the problems.

Bob Pecsok's film is available on NMR and some excellent film strips by Gateway are available on chromatography. There is also one available on electrophoreises which I find valuable at the end of 7B.

We cover all of Morrison and Boyd. In addition, 3 to 4 weeks of lab time are devoted to biochemistry of carbohydrates and proteins.

5. After we have gotten through introductory techniques, chromatography, three types of spectroscopy and related instrumentation, we consider gas chromatography. By this time students have all of the tools that are necessary to do good lab work.

6. We then give them some elementary qualitative organic analysis (wet analysis).

7. We do some Gringnard reactions in which biphenyl is a bi-product. I take some of the student's samples (or some old ones) and run appropriate NMR spectra so they can see the purity of their products. I also have them do IR studies.

8. We do a Friedel-Crafts reaction so that they will have experience with a reduced pressure distillation. By this time they have had simple distillation, fractional distillation, steam distillation and reduced pressure distillation. This puts us about 3/4 of the way through our 7A lab.

9. We do rates of chemical reactions. We have an excellent experiment which one of my students brought from UCLA. It complements the study of SN 1, SN 2, E 1 and E 2 phenomena, and it permits a study of first and second order reactions. This is a first order reaction which works well. Problems are given to test the student's knowledge of the experiment. He must do a valuable graphical interpretation. This experiment is popular with the students.

10. To wind up the lab for the first semester, we do analyses of alcohols including not only the classical work which differentiates alcohols, but also showing the appropriate spectra to tie things together. We're now through the first semester of lab and about half way through Morrison and Boyd.

11. In the second semester we utilize some of the techniques from the first semester and introduce a sequence synthesis because this is what students must do if they are going on in chemistry. Even if they are not, it still is a very good test of their technique. They must use the product of each step in each succeeding step. We use a four-step synthesis which takes about a month. Unfortunately, at the end of the month some students have not made any progress, but this is something that they have to accept.

12. Next, we do a kinetics experiment involving thermal control of the reaction.

13. After this, they choose the next experiment that they will do. For example, they can do the hydrolysis of nylon—although it may seem unimportant, it can be very interesting to students because they realize that there are different types of nylong and they get different results. Once these different products are assembled, you can do some elementary analysis using spectroscopy. The students can then see how they can use these tools to identify their products.

14. We have three to four weeks of qualitative analysis. The students are given three unknowns; the first one is easy, the second one is moderately difficult and the third one is quite difficult. They are expected to devise their own scheme of analysis. They can use their own books and other references. If they come to me, I can tell them whether or not what they want to do is feasible. I go over it with them and tell them if we have the appropriate reagents, etc. I do not let them use spectroscopy on the first unknown because that would immediately tell many of them what they had. When they bring their analysis to me, I approve it and then I will either give them the spectrum or possibly rerun the analysis. We follow this procedure on to the third analysis. The third one is usually so difficult that I give them the spectrum or the data immediately. You may wish to give only data since so much spectral information is available.

15. The remainder of the 7B laboratory is devoted to carbohydrates, amino acids and proteins. We include optical rotation in this section. We also use thin layer chromatography and electrophoresis.

By the time the El Camino student completes 7A, B, he has a good introduction to modern analytical techniques; he has a good background in organic chemistry; and he is capable of transferring into upper division courses and doing well.

CHANGING OF THE SECOND-YEAR CHEMISTRY CURRICULUM: PHYSICAL, ORGANIC-BIO, ANALYTICAL OR COMPOSITE

Norman Juster
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Presented as the Second Year Chemistry Keynote Speech, 20th Two-Year College Chemistry Conference, Fullerton, October 4, 1969

Historically, the second year course in two-year colleges was based on the type of training or education that was in vogue for many years at four-year institutions for chemistry majors. Non-chemistry majors, if they wanted a second year course in chemistry, had to sit through exactly the same course as majors. This was frequently an organic course or a year of quantitative analysis. Organic chemistry was principally a memory job: nomenclature, hundreds or organic reactions, synthesis approach to making compounds, and reactions to help determine structure. Analytical chemistry was traditionally gravimetric and volumetric work done by following detailed procedures.

Community college second year chemistry students are not usually chemistry majors. Chemistry majors in the second year course vary from institution to institution, constituting 5 to 25% of the chemistry students (average of 10%) throughout California. Pre-med students comprise form 20 to 40% of the students with an average of 25% taking the second year organic course. The percentage of pre-dental students ranges from 35 to 65%, with and average of about 50%. About 10 to 20% are in miscellaneous programs related to health and life sciences. This means that if 10% are chemistry majors, the other 90% of your chemistry students are pre-med, pre-dental and health and life science students.

When we talk about the type of course we are going to offer in the second year at the community college, we must keep out clientele in mind. We have a transfer problem from two-year to four-year colleges but with the number of people attending community colleges these days, perhaps we can convince four-year colleges that a second year course designed to handle our clientele will also suit their needs.

Quantitative analysis, a customary second year chemistry course, has evolved to become largely instrumental and less traditional. Instrumental techniques are becoming more and more useful and instruments are frequently semi-quantitative unless they are designed as an adjunct to a more exacting technique. In addition, we expect that some of the traditional wet quantitative analyses will find their way into all levels of courses, especially at the freshman level.

The first year course is also evolving. We know that there is much physical chemistry in it now and much of the descriptive chemistry has disappeared. Reaction theory, thermodynamics, quantitative analysis principles, equilibrium principles, kinetics and even some instrumentation introductions are discussed.

Organic chemistry is also changing. The role of synthesis, I think, has been recognized as a topic which has been given undue emphasis. Actually, the tricks of doing synthetic sequences have limited use for 90% of our clientele. I'm not sure it is of great use to the chemistry major. In fact, if he has a good foundation in some of the principles of organic structure and chemical dynamics, he can probably easily handle a course devoted solely to synthetic procedures. As taught at the introductory level, syntheses and reactions are very, very unrealistic. It's a mental exercise divorced from such practicalities as conditions (temperature, solvents, catalysts), side products and isolation techniques. Students usually do some of these things, but it is usually by a cookbook technique.

Modern organic chemistry practice requires understanding of reaction theory to answer questions concerning the role of the solvent, concepts of molecular engineering, and things that are sometimes barely mentioned in the second year course (photochemistry, high pressure chemistry, etc.). Some synthesis, of course, is useful, but I think it should be tied in very strongly and follow a good discussion of reaction theory, chemical dynamics and the connection between molecular structures and properties. There is room for the introduction of modern, analytical techniques and instrumentation and increased emphasis on natural products in biochemistry. There is a tremendous amount of exciting development going on at a very elemental level in biochemistry if it is connected with molecular structure. Many institutions require a year of chemistry before Biology I. It is useful to the modern biology student to concurrently take a second year chemistry course that treats molecular structure while he is studying molecular biology. It should be exciting for a pre-medical or pre-dental student to uncover interesting relationships between structural features and physiological functions. The principles of genetic engineering, virus control, and chemical relationships to physiological and biological functions are exciting. Furthermore, pre-medical students should be aware that many malpractice suits have been based on the fact that insufficient knowledge of this sort has lead to a misassignment of treatment for a particular patient.

A course in organic chemistry or quantitative analysis can always be flavored with natural products to make it much more immediate and relevant to the student's interests and needs. It should be a composite course, including analytical techniques, physical chemistry concepts, organic chemistry and natural products, molecular biochemical applications and instrumental analysis. Maybe this is not really organic chemistry, but the traditional subdivisions are rapidly fading. We have instituted a second-year course like this that is similar to UCLA's course. Our enrollment has nearly doubled in two years. This indicates some student acceptance. Students that have transferred have reported not only no difficulty, but good results after taking the composite course.

Such a course is expensive; however, staggering experiments helps to defray costs. There are some rather expensive chemicals needed such as enzymes and DNA. We purchase one enzyme that costs $1/microgram. Fortunately we do not need very much. Compared to the costs for large quantities of more common materials for synthetic procedures, these expenses are not out of line.

Our lecture schedule is generally unchanged. We begin primarily by discussing structure on a rather static basis and use some instrumental techniques to provide evidence about structure. We discuss the relationship between structure and properties—the various related physical and chemical properties, solubility, boiling point, reacton theory, review of thermodynamics and types of organic reactions. We spend another section on organic reactions and proceed into biochemistry.

About one-fourth of our year is spent on biochemistry with a separate text. The quantitative work is in the laboratory course which also has a laboratory lecture. We use Prof. Pecsok's text and laboratory manual. Another fourth of our year is based on phase changes involving separations and semi-quantitative techniques; an additional fourth deals with instrumentation like spectroscopy and spectroscopic techniques, and some aqueous and non-aqueous chemistry involving titrations and the uses of the pH meter. The last fourth of the one-year course is roughly divided into such topics as kinetics, radiochemistry and other special quantitative techniques that are just being developed.

When the student takes the biochemistry part of the course, he finds the same principles in the lab are used again and this emphasizes the unifying principles throughout chemistry. It is also very useful to the teacher because the student gets a second crack at some of these principles and winds up just a little bit better prepared.

PUTTING QUANTITATIVE ANALYSIS BACK IN THE CURRICULUM

William Guenther
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Summary of presentation to the Second-Year Chemistry Course Section, 23rd Two-Year College Chemistry Conference, Chicago, September 12, 1970.

It was felt that classical methods of analysis should be returned to the curriculum. Some of the techniques may be learned in freshman courses with the remainder being taught in the second year analytical course.

From a random survey of eighty articles in *Journal of American Chemical Society* and *Journal of Inorganic chemistry*, the frequency of analytical techniques used was tabulated:

	Journal of A. C. S.	*Journal of Inorganic Chemistry*
Total Papers	34	46
Spectrophotometry	17	31
NMR	11	13
Titrations	3	10
X-Rays	4	9
Mass Spectra	6	5
Gas Chromatography	7	1

Elemental analysis, ion exchange, pH meter and different types of chromatography are instruments and techniques that must be learned by students.

Many colleges have abandoned teaching traditional quantitative analysis. Many difficult techniques and calculations may be mentioned in the freshman class, but can be taught effectively only at the expense of many other topics.

INTRODUCTION OF A BASIC INSTRUMENTAL ANALYSIS COURSE IN A SMALL, PRIVATE JUNIOR COLLEGE

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Invited paper prepared for *Chemistry in the Two-Year Colleges*, 1969.

With the advent of the NSF Science Equipment Program and other programs of this type, both large and small colleges have had the opportunity to increase their science equipment holdings. These increases have and should improve the chemistry curriculum by both improving existing programs and also beginning new ones. It is extremely important that before any new program is begun, the existing programs should be functioning well.

Hiwassee College offers two programs in general chemistry; the same text is used for both, but the approach and depth of material are different. The division in these programs is made on the basis of chemistry background and ACT test scores. The average number of students per year in these courses is 110 students out of a total enrollment of 625 students. The organic chemistry course is a three quarter sequence with one year of general chemistry as a prerequisite. The average enrollment is fifteen students per quarter.

In 1964 Hiwassee was awarded an NSF grant for equipment purchases to improve the pre-medical aspects of the program. Purchases from this grant were made from 1964 to 1966.

Most of the equipment purchased was being used infrequently in the chemistry courses because the planned curriculum changes could not be relized in a short time. At the same time new equipment was sitting idle, our needs for basic supplies and equipment for our general course offerings became critical. In 1966 we did not apply for an NSF grant but instead spent all of our allocated fund to improve our basic laboratory situation.

Today we are probably as well equipped as most small, two-year colleges. Our general chemistry laboratories have a maximum of twenty students per period. All students work individually with their own glassware and equipment. Each organic student has a ground glassware kit and support frames. Organic students use some instruments such as melting point apparatus, the analytical balance and an Abbe refractometer to determine purity and concentration of their products. We plan to purchase a UV-visible spectrophotometer, a gas chromatograph and an IR spectrophotometer. We feel that this would improve our laboratory facilities very much.

Feeling that the regular laboratories and classes were adequately staffed and equipped, we felt justified in offering an introductory instrumental analysis course on a one quarter basis. We had the instruments and equipment for the course and also felt that it would serve a student need. We had much help and encouragement from staff members of the Teacher Training Division of the Oak Ridge Associated Universities.

Fundamentally we have a laboratory course designed to acquaint the student with the theory, operation, limitations and uses of basic laboratory instruments. The course includes experiments in the following areas:

I. Separation Methods
  A. Paper Chromatography
    1. Separation of inks
    2. Separation of sugars
  B. Thin-Layer Chromatography
    1. Selected experiments in thin-layer chromatography; quantitative, preparative, qualitative, reaction kinetics, natural product separation, purification of organic materials
II. Optical Methods
  A. Spectrophotometry—Lambert's and Beer's Laws
    1. Determination of absorption spectrum of Cr^{+++} solution of known and unknown concentrations
    2. Simultaneous analysis of two-component mixture of Cr^{+++} and Co^{++}
  B. Polarimetry
    1. Determination of concentrations of optically active substances
III. Electrometric Methods
  A. Conductrometric
    Titrations of HCl and HOAc with NaOH to determine Ka for acetic acid using the conductance bridge
  B. Potentiometric Method
    pH titration of H_3PO_4 mixtures for determination of K_2 using pH meter

IV. Radiochemical Methods
   A. Operation and characteristics of Geiger-Mueller tube
      1. Plateau
      2. Background
   B. Alpha, beta and gamma radiation
   C. Half-value layer
   D. Half-life of iodine 131

The course is on the sophomore level with the prerequisites of one year of general chemistry and one year of intermediate mathematics. Last year twelve students enrolled in the course over the three quarters and we were pleased with the results both in student progress and their attitude toward the course. We plan to expand the program in the future as time and money permit and offer more experiences for our students.

COMMUNITY SERVICE CHEMISTRY PROGRAMS AT CHIPOLA JUNIOR COLLEGE

Joyner Sims
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Invited paper prepared for *Chemistry in the Two-Year Colleges*, May 21, 1971.

The chemistry department at Chipola Junior College has been engaged in a variety of community service activities since 1968. These include three non-credit short courses, a three-semester-hour instrumental analysis course, four equipment demonstrations and two seminars presented by prominent chemists. All programs have been scheduled as evening events and, with the exception of the seminars, were designed primarily for community service. The participation of area industrial personnel, science teachers and government employees has been excellent and plans are being made for similar activities for the next school year.

The most extensive experience with community service programs in chemistry at Chipola has been with non-credit short courses. A short course on Infrared Spectroscopy was offered during the fall semester, 1968. A second short course on Gas Chromatography and Visible Spectroscopy was offered the spring semester, 1969, and a third program on Electroanalytical Chemistry was given during the spring semester, 1970. In each course the method of instruction was an informal lecture-discussion. The enrollments were 12, 26 and 20 students respectively.

Each course consisted of twelve and one-half hours of instruction during five sessions over a period of either two and one-half weeks or five weeks. No written or oral examinations were given. Of the 58 participants, 45% were industrial chemists or industrial laboratory technicians from Panama City or Port St. Joe, Florida, or Cedar Springs, Georgia. Thirty-five percent of the participants were science teachers. None of the group were full-time Chipola students. The total cost of all three courses *including* instructor salaries was less than $700.

The Infrared Spectroscopy course was structured around the American Chemical Society's filmed short course prepared by Norman B. Colthup. The film was prefaced by two lectures on the fundamental principles of spectroscopy and followed by a demonstration of the Perkin-Elmer Model 700 Infrared Spectrophotometer. No textbook was required for the course but Gordon Barrow's[1] book, *The Structure of Molecules*, was recommended reading.

The second short course consisted of two lectures on the fundamental principles of gas chromatography and two lectures on the fundamental principles of visible spectroscopy followed by a demonstration of the Coleman Model 21 Flame Photometer, the Coleman Model 14 Spectrophotometer, the Perkin-Elmer Model 390B Atomic Absorption Spectrophotometer and the Carle Model 6500 Basic Gas Chromatograph. More than 150 transparencies were used for the lecture and laboratory presentations. No textbooks were required for the course but *Instrumental Methods of Analysis* by Willard, Merritt and Dean[2] was a recommended reference.

The third short course consisted of five lectures on the fundamental principles of electroanalytical chemistry which included a consideration of the applications and limitations of more than fifteen analytical techniques. Two overhead projectors were operated simultaneously and more than 150 transparencies were used during the five sessions. No textbook was required for the course, but several references were recommended including Lingane's[3] book, *Electroanalytical Chemistry*.

A belated, written evaluation of the short courses was obtained in February, 1971. Forty percent of the group completed and returned an evaluation form. Sixty-nine percent of those responding indicated that they would recommend the course(s) to a friend. Eighty-eight percent indicated that almost all of the class time was well spent. Twenty-four percent indicated that the material should have been presented more slowly. A number of other helpful suggestions were included in the responses. Of the 58 participants in the three short courses, 26 individuals attended only one course, 13 persons attended two of the courses and two people attended all three courses.

The most acute problem encountered in offering short courses was communicating with potential participants. A computerized mailing list was established between the second and third course. It has been updated and extended periodically and used extensively in subsequent programs. Official college news releases and a current mailing list have solved the communications problem.

Experience with short courses suggested a need for a community service introductory instrumental analysis course. A survey was conducted in May, 1970. There was sufficient interest to proceed with a new course. The college curriculum committee had earlier approved the course to be offered on demand as a part of the evening program during the fall semester, 1970. The catalog description of the course is as follows:

> NSC 290, Modern Methods of Analysis.
>
> A course designed for science teachers, clinical technologists, chemists and others who need an introduction to modern analytical methods in the sciences, especially those of separation, spectrometric methods for the study of molecular structure, and electrochemical and radiochemical methods. Prerequisite: at least six semester hours in the natural science area, including general chemistry. Three semester hours credit.

The course most closely resembles the lecture portion of a junior or senior level instrumental analysis course in most chemistry degree programs. It was designed to emphasize the usefulness of analytical techniques to science disciplines other than chemistry. The course was *not* designed to be the equivalent of any other course in any curriculum. Chipola freshmen and sophomore science majors were not permitted to enroll in the course. For these reasons it was entitled Natural Science 290.

Nine persons enrolled in the course. This included one of our faculty, three area science teachers, an industrial chemist, a medical technologist, two science instructors from a neighboring junior college and a recent computer science graduate. Two of the nine students elected to audit the course.

Classes met three hours a week for fifteen weeks. The course was taught with the aid of demonstrations, slides, transparencies, film loops and films. No examinations were given. Instead, problems and questions were prepared for participants to complete between sessions with the use of any reference books available. The major topics of the course are listed below:

1. Treatment of Analytical Data
2. Separations Based on Phase Changes
3. Extractions
4. Chromatography
5. Thermal Analysis
6. Nuclear Magnetic Resonance Spectroscopy
7. Infrared Spectroscopy
8. Ultraviolet Spectroscopy
9. Mass Spectroscopy
10. Atomic Absorption Spectroscopy
11. Electrochemical Measurements
12. Radiochemical Methods

Highlights of the course included the demonstration of four analytical instruments. On request, the Perkin-Elmer Corporation demonstrated their Model 990 Gas Chromatograph, Coleman Instruments demonstrated their Model 124 Visible-Ultraviolet Spectrophotometer, and Scientific Products demonstrated the Bausch and Lomb AC2-20 Atomic Absorption Spectrophotometer. In addition, a Sargent Model XVI Polarograph was received on loan from Sargent-Welch Scientific Company for demonstration. Each of the programs was announced well in advance and interested persons in the area were invited to attend.

Brochures and other materials of educational value were obtained on request from several companies. This proved to be an abundant source of useful materials for the course. Beckman Instruments Bulletin 295-B on spectrophotometry and 7079-A on electroanalysis are just two examples. The Varian NMR film was also obtained on request at no cost.

The textbook selected for the course was the recent publication *Undergraduate Instrumental Analysis* by James W. Robinson[4]. It was most useful to students with the least experience in analytical chemistry. Modern Methods of Analysis will be offered again on demand next fall. Several suitable reference books for the course will be available for students to purchase. These will include the Robinson[4] book, the Pecsok and Shields[5] book and the Willard, Merritt, and Dean[2] text. None of these include all topics discussed as notes are prepared from more than twenty references.

There was no formal evaluation of the course by students or employers of students. However, an almost perfect attendance record and informal conversations with students indicate that the course was worthwhile.

The total cost of the course including the instructor's salary was less than $600.

Chipola established a Natural Science Division Seminar Series for the first time last school year. Two of the programs were evening programs in chemistry. The speakers were asked to direct their remarks to freshman science students. The public was invited to attend. The two programs, "Metal Contaminants in the Environment" and "Metals and Enzymes," were well attended by students and area residents.

The development of community service programs and courses provide a refreshing escape from the rules and traditions that discourage innovation in transfer programs of community colleges. Let us hope that "articulation" will have no counterpart in emerging community services.

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THE CHALLENGE OF CHEMISTRY
TEACHING CHEMISTRY TO THE NON-SCIENCE MAJOR

Phillip Horrigan
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Presented as the Beginning Chemistry Keynote Speech at the Two-Year College Chemistry Conference, Baltimore, February 6, 1971.

For the chemistry major, the chemistry professor and the research chemist, chemistry is a continuing and steadfast challenge. Learning, correlating and applying new facts is fascinating and rewarding for these people. On the other hand, chemistry presents a different kind of challenge when we consider the teaching of this subject to the average non-science major. Taking into account the fearful attitude of most of these students toward science courses in general, it is truly a challenge to teach them chemistry.

I would like to present several facets of this topic as follows:

(a) Is it important for the non-science major to have an understanding of science, in general, or chemistry, in particular?
(b) Acknowledging the importance of chemistry for the non-science major, how should it be presented?
(c) Who should teach such a course?
(d) My personal experiences with this course at Southern Connecticut State College.

1. *Is it important?*

I don't believe that there ever has been more public attention focused on scientific matter. Everyone is concerned about pollution, drugs, food additives, smog, carcinogens, radioactive waste and nuclear energy. Certainly these topics and many related ones should be of deep concern to us all. We, through our elected and appointed representatives, must make wise decisions that affect us and will affect our children for generations. Unless the public understands the scientist and his work, it cannot make reasonable interpretations of the facts that are presented. Consequently the public will not be able to make wise decisions on scientific matters.

This problem is not unique with science and the non-scientist. A major in any field should have a basic understanding of the other fields of knowledge. A person who takes courses in a very narrow area will someday regret not knowing a little about another important area. I remember taking an economics course, which was one of my general requirements. The instructor and the course were extremely dull and uninteresting. All I can recall is that supply and demand have an inverse relationship. Some time later I operated a chemical business which did not turn out well. The products we sold were excellent, but the business acumen was not there. Perhaps a more lively and relevant economics course might have made the difference. This is an example of a scientist with a poor understanding of another important field.

As for the non-science major, some training in science is, I believe, a "must." A school may require one semester, two or even more. The context may be in physical or biological sciences or both. As for choosing a biological or physical science, I personally feel that as long as the course chosen is suitable for non-science majors, is interesting and relevant, it really does not matter which area is selected. The physical science course is usually chemistry, physics or a combination of both. The general student is often more frightened of physics than chemistry and if faced with a choice will generally pick chemistry. Recent changes in the approach to teaching physics will no doubt have an effect on this attitude. However, I think that since there can be considerable coverage of the principles of physics in the chemistry survey course then the choice should definitely be chemistry.

2. *How should it be presented?*

I have already mentioned student "attitude" toward chemistry and physics courses. It is this attitude, this mental block, so to speak, that we have to overcome. The average student has a fear of chemistry with its strange symbols, equations and particularly its mathematical operations. If we can overcome this fearful attitude we will be better able to communicate with the students that come to us.

Do we have to teach *general chemistry* to these non-science students? General chemistry is a foundation course that contains the basic principles and facts on which to build a larger structure of chemical knowledge. It is designed not as a survey of chemistry in general, but as a beginning course which must be added to in order for the student to get a complete picture. The chemistry major cannot fully appreciate all he has had to learn in general chemistry until it is applied and amplified in upper level courses in organic, physical and inorganic chemistry. Consequently, does it make sense to give the general chemistry course or an abbreviation of a general chemistry course to a non-science major? I think many college educators are agreeing now that a truly different approach is required.

What approach makes sense? Although there is probably more than one answer to this I will present what I think is a reasonable one. The student should learn, in as non-mathematical a way as possible, the basic principles of chemistry. He should understand the structure of the atom, how bonding takes place, how elements are classified, what a chemical reaction is and how and what the chemist studies in the laboratory. He should be made aware of the scientific attitude, the types of research being performed and the various problems involved. He will be anxious to examine many of the applied areas where chemistry plays such an important role. Which areas and how many is up to the particular instructor. While covering these relevant areas, basic principles and facts can be expanded in a rather painless manner. Thus the non-science student will learn chemical facts and principles, what the chemist is doing and what role chemistry is playing in the world about us.

As for the scheduling of the course itself, it may be all lecture or lecture with laboratory. I have observed that laboratory exercises which are designed for this approach are well-liked by the students. Further the lab work allows great latitude in supplementing lecture material. In particular simple mathematical operations can be presented more easily in a laboratory atmosphere than in lecture.

3. *Who should teach it?*

Teaching a non-major survey course has long been a problem in every area. Professors often refer to these as the "baby" courses and feel that they would rather teach higher level courses to their own major students. As a result, the preparation and delivery of these courses have often been careless and substandard. The students detect this attitude and are "turned off." In chemistry, in particular, instructors have been known to walk into class each day with a piece of chalk and present one problem after another. This keeps the class quite busy, confused and uninterested. Recently, however, students are speaking up and are demanding better courses and more flexibility in choosing the courses that they must take. At the same time many instructors who have recognized the need for improvement in the non-science major chem course are doing something about it. Who then should teach the course? Certainly any chemistry instructor who *believes* it is worthwhile to communicate chemistry to the non-science major. If he feels that this is an important mission rather than an assigned chore he should teach the course and he will do a good job.

4. *My own experiences with a non-science major chemistry course at Southern Connecticut State College.*

When I was first assigned to this class I followed the course outline and recognized right away that something was wrong. It was like a one semester course in general chemistry. The students were terrified and most went away dissatisfied. This past semester I had an opportunity to teach the course in a new way. I had 94 students. We met for two one hour lecture periods and one two hour lab period. The course proceeded as I have already suggested. We had some lively lecture discussions and the class seemed to enjoy specially designed laboratory exercises. Each student wrote a term paper on something that was chemistry related and of interest to himself. I received some excellent papers! Obviously the students were anxious to get involved in certain topics. Finally, I must tell you that although there were 94 students in the course this semester I have 544 signed up for the spring semester. I can only think that we must be doing something right.

A SUGGESTED CHEMISTRY COURSE FOR INHALATION THERAPY STUDENTS

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Presented at the Chemistry for Health Professions Section at the 25th Two Year College Chemistry Conference, Baltimore, February 6, 1971.

Today there is something approaching one hundred or so community or junior colleges either conducting a complete curriculum in inhalation therapy or providing college-level courses for inhalation therapy students from hospital-oriented schools. Since many of you are not familiar with the relatively new allied medical specialty of inhalation therapy, I should like to begin by briefly describing what an inhalation therapist and an inhalation therapy technician do and discuss for your edification the background and training of most persons coming into college chemistry courses in inhalation therapy curricula.

Inhalation therapy is an allied health specialty in the treatment, management, control and care of patients with deficiencies and abnormalities associated with the processes of breathing. The inhalation therapy specialist, which includes both inhalation therapists and inhalation therapy technicians, must be expert in the therapeutic uses of such aids to the breathing process as medical gases, oxygen administering apparatus, humidification, aerosols, positive pressure ventilation, chest physiotherapy, cardiopulmonary resuscitation, and mechanical airways.

Inhalation therapy is used primarily in the treatment of heart and lung ailments, such as cardiac failure, asthma, pulmonary edema, emphysema, cerebral thrombosis, drowning, hemorrhage, and shock.

Also, inhalation therapy employs a variety of testing techniques to assist in diagnoses and medical research.

What specifically are the duties and responsibilities of the inhalation therapy personnel? The inhalation therapy specialist serves the patient, following specific instructions from the physician. To do this effectively, he must understand the physical and psychological needs of the patient, the doctor's goal in using inhalation therapy, and just where and how a specialist's equipment and know-how fit into the treatment picture. He deals directly with patients and their families, as well as doctors, nurses, and other hospital staff. He must be thoroughly familiar with the technical operation of his equipment in the application of the various inhalation therapy techniques to specific patients. He is given the responsibility to teach patients, nurses, interns and others, especially at the bedside, as questions arise regarding techniques and equipment.

Hospitals are the largest employers of inhalation therapy personnel. Inhalation therapy departments are considered necessary at general hospitals and medical authorities now advise their establishment at hospitals as small as fifty beds. Many of the larger, more progressive departments have in excess of fifty inhalation therapy personnel. The rapid growth of inhalation therapy training programs at hospitals, vocational-technical schools, junior and community colleges, and other college programs are opening new jobs for those who wish to teach. Qualified inhalation therapy personnel are in demand throughout the world as workers and teachers.

The rapid increase in the technical complexity and variety of inhalation therapy used in patient care has resulted in two general classifications of specialists -- inhalation therapists and inhalation therapy technicians.

Both specialists must be fully capable, under medical supervision, of administering to patients the therapeutic and diagnostic procedures of inhalation therapy and of cleaning, sterilizing, and maintaining inhalation therapy equipment. Based on his advanced educational background, the inhalation therapist is given greater responsibility in patient care, teaching, research, and department supervision in the development of the field of inhalation therapy. The therapist has more opportunity for immediate advancement and is in a higher salary bracket.

In order to be eligible to sit for the National Registry Exams for inhalation therapists, one must have an associate degree or the minimum of two years of college, and be a graduate of an AMA school of inhalation therapy. Most therapist training programs are now college-based, affiliated with one or more hospitals for bedside clinical experience, and provide the student with classes in the biological and physical sciences as well as in general education background. The therapist is taught not only how to do it, but much emphasis is placed on the theory of what he is doing.

The technician, on the other hand, receives his training for the most part in an on-the-job type setting in programs conducted within inhalation therapy departments in a hospital. Most technician training programs are of one year's duration and do not grant any college credit. The emphasis in a technician training program is on how to do it and to prepare an individual to be able to perform the basic and routine types of inhalation therapy effectively and safely, but with only elementary understanding of why he is doing so.

Now, what are the chemistry needs of students in two-year associate degree inhalation therapy programs? First of all, it must be kept in mind that most of these students may not have had any chemistry or physics in high school and that most are not going on to further chemistry courses or to education beyond the associate degree. Although I am not a chemistry teacher, I should like to attempt to outline for you what I feel would be a chemistry course for inhalation therapy students. This course would be conducted over a fifteen-week semester with three hours of lecture and a two-hour lab each week. The course should be designed as a survey in the fundamental laws and theories of chemistry, but be of a practical and applied nature rather than with heavy emphasis on theory such as is commonly found in freshman chemistry courses for chemistry majors or even for pre-med or similar type students.

The first three weeks of the course should be devoted to basic concepts and definitions. This block could start off with a discussion of the history of chemistry and the various divisions of the chemical sciences. One might then briefly present and discuss the following areas: metric system, mass, weight, elements, symbols, compounds, mixtures and formulae. This would be followed by a discussion of the atom and its composition, atomic weight, periodic classification, the molecule, molecular weight, and Avogadro's Law. States of matter, physical and chemical changes, equations, types of chemical reactions, laws of conservation of mass and energy, laws of definition composition and multiple proportions would complete the first three-week block. Obviously, the above material might provide enough meat for a full semester's course. However, I must again emphasize that the primary purpose for this chemistry course for inhalation therapy students is to provide them with a fundamental background and with basic knowledge and definitions which they may be able to apply to their inhalation therapy subjects later in their training. This is strictly a survey course and the instructors must realize that much material will be left uncovered and much must be left unsaid in a course intended to be as broad as this one.

The lab associated with the first three weeks of the course might include an introduction to basic laboratory techniques and the scientific method and perhaps some elementary experiments in such things as physical and chemical changes and types of chemical reactions as well as practice in formula writing and equation balancing.

The next three-week block would be devoted to looking at two elements -- hydrogen and oxygen. One week might be devoted to the element hydrogen and such things as its occurrence, preparation, physical properties, chemical behavior, would be discussed. The second week would be devoted to oxygen and the same things as above would be discussed with the addition of a discussion of oxygen's relation to biological systems. The third week could be spent on oxidation and reduction.

It would then seem logical to move into a four-week block covering the following subjects. The first week would be water and the following topics could be covered: composition, electrolysis, physical properties, chemical behavior, hydrolysis. The next week could be devoted to solutions and cover diffusion, dialysis, and osmosis. The third week would logically seem to be a discussion of electrolytes and ionization. Again, I would emphasize at this point that in discussing these topics, one could easily relate the chemistry to biological systems and bring up such things as isotonic, hypotonic and hypertonisity, blood plasma, electrolyte balance, water balance in the body, etc. The fourth week of this block could be devoted to acids, bases, salts, pH, buffers, molar and normal solutions, and again, all of this could be related to human and biological systems.

The next week could be spent on gas laws and should include brief discussions of Boyle's, Charles', Gay-Lussac's, and the combined gas laws. Also, properties of gases at extreme temperatures and pressures, critical temperature and pressure, and triple points should be mentioned. The following week should be spent on the halogen family and in a brief discussion of some of the important metals such as sodium, potassium, calcium, iron, mercury, etc. The following week would be continued with some of the important non-metals such as nitrogen, ammonia, sulphur, etc., and with the inorganic carbon compounds of carbon dioxide and carbon monoxide.

The last two weeks of the course could be devoted to organic chemistry and would only generally touch on such things as general principles and classifications of organic compounds and organic chemistry as applied to bodily functions, such as enzymes, digestions, metabolism, etc.

I am sure that to the professional chemistry educator the above outline seems like an impossible task to complete in one semester. I believe, however, that it can be done if one carefully considers the aims and objectives of this course and structures it accordingly. I do believe, however, that the selection of a textbook and perhaps a laboratory manual for this course is most important and would suggest a book which I feel is at about the right level for inhalation therapy students and would fit well into a course in chemistry such as I have outlined. The book is entitled *Principles of Chemistry*, by Joseph Roe, published by C. V. Mosby. I might also mention that it may be most helpful to the chemistry instructor to confer with the inhalation therapy instructor and perhaps to make use of the student's inhalation therapy texts for some of the chemistry course reading and problem solving. We have found this to be quite useful in showing the student how the chemistry directly relates to his inhalation therapy. One of the inhalation therapy texts widely used is entitled *Fundamentals of Inhalation Therapy,* by Donald Egan, published by C. V. Mosby. This book contains a large section on chemistry in inhalation therapy and it can be used for supplemental reading and also for some problem solving.

ALLIED HEALTH CHEMISTRY – NO SUCH THING!

Howard Taub
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Presented as the Chemistry for Non-Science Majors Keynote Speech,
26th Two-Year College Chemistry Conference, Los Angeles, March 27, 1971.

From 1950 to 1966 the total work force increased by *29%.*

During these same years, the number of allied health workers increased by *90%.*

From 1966 to 1975, a 40% additional increase is predicted – that means *one million* more individuals, most of college age, are now in the process of entering a health field.

In addition, *secondary* school systems such as the State Board of Education in Oregon and the Los Angeles City School District are exposing students to the health occupations by setting up allied health clusters in their curricula.

How are all of these pressures going to affect community colleges, especially their science departments? One thing is certain: the faculties involved will have the responsibility for training and educating increasing numbers of allied health workers because trade schools and on-the-job training programs will not be able to keep up with the demand for more and better health services.

The question to be discussed here asks, "How is an allied health course set up and what chemistry should be included in it?"

One approach to setting up a new course is to do what others are doing. An example of this occurred at a local community college. Half of the students were flunking the physiology course for nurses during the first year because they didn't know the fundamentals of *human anatomy.* These fundamentals are *supposed* to be taught in a prerequisite, general anatomy course for all students which requires the dissection of a cat. Consequently, although the students knew all about the location of the nerves, muscles and bones of a cat, they knew nothing about human anatomy! The instructor's justification for using this method instead of one which teaches *human* anatomy is the fact that "everyone dissects cats in anatomy classes."

In the same way, chemistry courses which cover difficult, abstract chemistry principles designed for allied health students could result in the failure of these students. Let us look at the chemistry courses listed by a couple of community colleges.

An Eastern community college bulletin schedules the following two beginning courses.

EASTERN COMMUNITY COLLEGE

Chem II Principles of Chemistry I (3 class hours per week)

For students not majoring in physical science or engineering science. Modern concepts of atomic and molecular structure and periodicity; chemical bonding; stoichiometry; solutions; states of matter; introduction to chemical equilibrium. 3 credits.

Chem 100 General Chemistry I (3 class hours per week)

A study of the fundamental principles and laws concerning the structure and behavior of matter. 3 credits.

Which one is intended for allied health workers? Is it the top one for non-majors? Some of the concepts listed might frighten some of the students who have poor science and math backgrounds. The one listed at the bottom is the regular chemistry course for science majors.

Let's look at a West Coast community college offering.

WEST COAST COMMUNITY COLLEGE

Chem 1 General Chemistry (5)

Lecture 3 hours; laboratory and quiz 6 hours. Prerequisite is one year of high school chemistry or Chemistry 3. Deals with the principles and laws of chemistry as related to the structure of matter.

Chem 3 Introductory Chemistry (5)

Introduces chemical concepts and the properties of matter.

Chem 4 Basic Chemistry (3)

Presents a descriptive survey of the more important chemical concepts.

Here are three courses. Note the first course listed has a prerequisite calling for either high school chemistry or Chemistry 3. If Chemistry 3 (Introductory Chemistry) is equivalent to high school chemistry, to what is Chemistry 4 (Basic Chemistry) equivalent?

Which of the three is best for allied health students: the science major course, the high school make-up course, or the course for "non-readers"? Confusing? Yes, it is to the student as well as to the instructor who is asked to set up a chemistry course for allied health students.

A second approach to determining chemistry needs is to consult with the professionals in the allied health field. These are the individuals who have worked in one or more allied health fields, have advanced to the top level (usually acquiring an advanced degree along the way) and have taught at a college or other educational facility. At our Allied Health Professions Project this type of individual serves as an associate director with specialties in one or more of the allied health fields. It is interesting to point out that the kind of information I received when I questioned these experts depended on *how the question was phrased.*

First Question - "What chemistry should a nurse (dental technician, laboratory technician, etc.) take?

The immediate response in all cases was: "Qualitative chemistry, quantitative chemistry, organic chemistry and perhaps biochemistry."

Second Question - "What chemistry should an entry-level person in your field take?"

There was always a brief delay, and the answers were then almost all unanimous – "NONE." There is nothing contradictory about these two answers although they may seem to be in conflict. To both respondents the term "chemistry" meant the classical science major course. In answering the first question, the experts had in mind students who were going on to earn a four-year degree; in the second case they were thinking of the beginning aide or assistant.

Both kinds of students will be enrolled in the "typical" community college allied health class since most students are undecided about their major at this level. However, if the Los Angeles Times article of March 9, 1971, headlined "College System Flunking Test of Relevancy, Educators Warn" is correct when it quotes a government-appointed task force that states "of the million students who enter college each year, only half will complete two years of study and only a third will complete four years," then 50% of your students will be terminal. The majority of the allied health students will become entry-level workers in the health field.

All I've said here so far is that a horde of allied health students will be stampeding the college; that the present science major course is fine for the baccalaureate students, but for most of the allied health students *no* chemistry course is needed.

Not only will these statements *not* be well received, but it could be downright "dangerous" to say them to college chemistry teachers who might be thinking that if there are no allied health chemistry courses, no chemistry teachers are needed! This would certainly *not* be the case when a third approach is considered to determine chemistry needs for allied health workers besides "doing what others are doing" or "seeking advice from professional workers."

A rephrased question needs to be asked.

Rephrased Question - "What chemical concepts does an entry-level health worker *need*?"

The third approach is aimed at actually finding out what allied health workers do, then pulling out chemistry content from their tasks in an effort to derive basic concepts to formulate instructional units.

During the first year of operation, our Project conducted a national survey on 20 of the more than 100 allied health occupations. More than 4,000 individual tasks were included. Of these, I selected four tasks that were performed by a high percentage of workers in almost all of the allied health fields. The tasks, chemical content and basic concepts are shown in Table 1.

Table 1
Tasks and Concepts for Allied Health Workers

Tasks	*Chemical Content*	*Basic Concepts*
1. Clean and/or sterilize areas, supplies or equipment.	– Chemistry of cleaning materials – Chemical reaction rates – Chemical sterilization	Chemical asepsis
2. Handle, distribute and dispose of materials containing corrosive chemicals or preservatives.	– Chemistry of acids and bases – Laboratory safety and first aid – Chemical symbols and formula	Chemicals and chemical reactions
3. Prepare materials, solutions, media, etc.	– Chemical symbols and formula – Properties of solutes and solvents – Concentration of solutions – Weight/volume measurements	
4. Give emergency care or attend to a patient.	– Chemical balance of body systems	Homeostasis

(See Appendix I for an expanded listing of tasks and chemical concepts included in selected allied health fields.) For each basic concept there is an expanded content listing shown in Table 2. This information resulted from an analysis of tasks and chemical concepts for various allied health occupations as shown in Table 3.

Table 2
Sample of the Expanded Content Listing

Chemical Asepsis - Elimination of infectious agents through the use of chemical application. 1. Classification of chemicals used in asepsis A. Antiseptics - Names, formulas, properties B. Disinfectants - Names, formulas, properties 2. Chemical reactions 3. Reaction rates 4. Chemical safety and first aid
Chemicals and Chemical Reactions 1. Classes of chemicals: Acids, bases, and salts – their properties – exothermic reactions 2. Solutions: Solutes, solvents, concentrations 3. Weight and volume measurements 4. Kinetics 5. Reaction rates
Homeostasis - "Static like" - A tendency toward stability in the normal body state. 1. Equilibrium and steady state processes in the body 2. Acid/base balance: Hydrogen ion, carbonic acid, pH 3. Electrolyte balance: Sodium, potassium chloride ions 4. Glucose/insulin balance: Acetone 5. Chemistry of foods that affect homeostasis: Solubility equilibria 6. Colligative property: Osmotic pressure and homeostasis

Table 3
Tasks and Chemical Concepts
Included in Selected Allied Health Fields

Tasks	*Chemical Content*
Nurses	
Carry out aseptic technique.	– chemical asepsis
Prepare and give between-meal nourishment.	– chemical elements related to health and illness – homeostasis
Observe, measure and record food and fluid intake.	– metric measurements of weight and volume
Use soaps and solutions in caring for patients.	– chemical symbols and formulas – alkalis and their reactions – concentrations and dilutions of solutions

(cont.)

Table 3 (cont.)

Tasks	*Chemical Content*
Handle and dispose of contaminated materials. Obtain and deliver supplies and equipment. Test urine samples for nonchemical content.	– chemical asepsis – chemical safety – acids/bases – chemical nomenclature – chemical reactions involving their rates
Dental Assistants	
Wash instruments.	– chemistry of cleaning solutions – asepsis
Prepare fillings. Handle chemicals.	– properties of metals (Ag, Hg) – laboratory safety – acids/bases
Medical Laboratory Assistants	
Prepare solutions and media.	– chemical symbols and formulas – solutes/solvents – concentrations (molar and percent) – weight/volume measurements
Use preservatives.	– acids/bases – laboratory safety
Inhalation Therapists	
Run blood gas and pH tests on patients. Observe for acidous/alkalous. Inject radioisotopes.	– homeostasis – acids/bases – acid/base reactions – reaction rates – concentration of solutions – metric weight/volume measurements – identify chemical symbols and formulas
Medical Assistants	
Use chemical disinfectants.	– asepsis – reactions of chemicals
Make dilutions.	– concentrations of solutions – weight/volume metric measurements
Handle specimens with preservatives.	– chemistry of preservatives – acid/base safety
Pharmacy Technicians	
Add drugs to prepare IV solutions.	– asepsis – concentrations of solutions – weight/volume measurements
Identify drugs.	– chemical symbols/formulas – use periodic chart
Observe drugs for spoilage or decomposition.	– chemical reactions involving temperature, water and air

(cont.)

Table 3 (cont.)

Tasks	*Chemical Content*
Laundry and Linen Workers Use caustic chemicals. Clean and sterilize materials.	– acid/base safety – asepsis
Housekeepers Use chemical solutions for cleaning.	– asepsis – chemical reactions – alkalis/acids
Food Service Dieticians Prepare menu for various prescribed patient diets.	– chemical elements related to health and illness – homeostasis
Sanitation Engineers Check for pollution of food, water and sewage.	– asepsis – chemical pollutants

In a similar manner additional basic concepts could probably be developed to provide enough content for a semester course called "Chemical Concepts in Allied Health," but *not* "Allied Health Chemistry." The latter name will only compound the confusion caused by the many types of chemistry courses presently in existence.

It is suggested that each chemical principle be applied or related to tasks performed by allied health workers and should not be taught as an abstraction. For example, if percent concentration is the subject, use an example of a nurse who prior to giving an injection is required to prepare 5cc of a 2% saline solution from a 5% stock solution.

In summary, there appear to be three approaches that you or your department can use to handle the chemistry needs of the many allied health workers who are now or will shortly be in your schools.

1. One, of course, is to leave things as they are in many schools where the allied health students are required to take one of the regular or watered-down chemistry offerings. As the number of failures continues to increase, as it surely will, you can rationalize that these students should not be taking chemistry and ought to change to another non-science major. Many will do just that, while others will drop out of college – with the result that some good allied health personnel will be lost.
2. A second approach is to give lip-service to the need for meaningful courses for allied health workers, but let the health faculty handle everything. There should then be no complaints when the instructor with little up-to-date chemistry knowledge teaches that an atom is a small electron ball moving in a circular orbit around a large nuclear ball, and his students come away thinking that this miniature solar system is held together with a wooden stick.
3. Whether you teach the course or not, the third and only vital approach is for you to become an active participant by assuring that each chemical *concept* included in the course will be accurate, up-to-date, and relevant to student needs. Then whatever chemical knowledge the student acquires will be equivalent in essence, if not in depth, to the content in the regular chemistry course. This will lay a good foundation for any further work in science the student will undertake.

I hope you will choose the last approach.

CHEMISTRY FOR NURSES:
A REAPPRAISAL OF THE COURSE CONTENT

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*Invited paper prepared for *Chemistry in the Two-Year Colleges*, March 1971

During a two week workshop in the summer of 1970, a group of chemical educators in New Jersey developed a series of guidelines for the role of chemistry in the education of nurses. This workshop, part of a series, was sponsored by a grant from the National Science Foundation to Rutgers University under the NSF College Science Improvement Program (COSIP) for two-year colleges. Participating in the workshop, entitled "Chemistry for Nurses," were educators from nine of the fourteen two-year county colleges of New Jersey, four of the six New Jersey four-year colleges and universities which offer a baccalaureate in Nursing, and eight hospital schools of nursing. Speakers included representatives from the Diploma Schools, Associate Degree Programs, and Baccalaureate Programs, as well as from the National League for Nursing, the American Nursing Association, the New Jersey State Board of Nursing, and the Connecticut State Department of Health. The following recommendations were developed in this workshop:

1. That a one semester course, following the general outline to be described, be considered essential for the Associate Degree and Diploma Programs.
2. That high school chemistry or its equivalent be made a requirement for admission to the Associate Degree or Diploma Programs.
3. That nursing departments of the community college be advised of the primary importance of chemistry as a basis for other science courses towards a greater understanding of the body in health and disease, and that this course takes precedence over physics or physical science if only a one semester course is scheduled to cover these areas.
4. That an advisory body be established to maintain a permanent communication between the nursing and science departments of the community colleges and to act as liaison between the academic institutions and the New Jersey State Board of Nursing. The advisory body should consist of dedicated and motivated teachers of nursing representing equally the hospital and academic institutions.

These recommendations were made to improve the quality of the Associate Degree Programs offered by the two-year colleges in view of the following:

1. limitations of time.
2. the varied educational and motivational background of the students.
3. the need for quality in the teaching process and student responsibilities.
4. communication between teaching staff and nursing personnel.
5. prerequisites for entering the nursing program.
6. a syllabus that would be realistic and cover those items of significance in educating the student both from a humanistic and practical point of view.

1. *A One Semester Course is Considered Essential for the Associate Degree and Diploma Programs.*

Chemistry is necessary in the nursing curriculum because it provides the knowledge essential for safe and effective nursing that is not ordinarily obtained in other science courses within a nursing curriculum. From a study of chemistry, nursing students will have a greater understanding of the subject matter taught in other science courses such as anatomy and physiology, microbiology, etc. Better laboratory techniques are developed. The interpretation and writing of reports, with reference to laboratory tests in particular, become more meaningful.

The trend today is toward utilizing community colleges as a training ground for students who wish to become registered nurses. Two-year diploma nursing schools are being phased out because, even with

Federal subsidies, their operating cost is becoming too expensive for hospitals to operate. When a nursing program must be completed within two academic years, it becomes necessary to be highly selective in what is taught throughout the curriculum. Not only must the State Nursing Board requirements be fulfilled, but also the requirements of the Board of Higher Education relative to obtaining a degree. Thus, in a curriculum crowded not only with courses, but also with clinical practice, a course in chemistry must be limited to a single semester. In the Baccalaureate Programs, where a future nurse is obtaining a broader educational background, there is room for more extensive and thorough training in not only chemistry, but some of the other basic sciences. Therefore, this workshop sharply focused on the chemical knowledge that a nurse must have; it discussed course content to meet these needs of the students.

Chemistry is itself an abstract and complex science. Since chemistry students, for example, cannot hold or see a single atom, ion or molecule, this concept must be accepted on faith. Because of this problem, sophisticated strategies must be implemented in order for the student to gain an understanding in chemistry. To teach a relevant course in chemistry within the time limit of one semester becomes a challenge. To best meet this challenge, much effort should be expended in developing "learning packages" by using audio-visual-tutorial media. That is not to suggest that the traditional lectures, seminars, and laboratories be abandoned, but that these learning packages supplement and reinforce the other methods of teaching. This instructional concept allows the student to learn at his own pace.

The development of learning objectives for this chemistry course would be an invaluable aid to both the student and the instructor. By showing the student what he is responsible for on the first day of class, he will be better able to budget his time in accomplishing his objectives. The student can proceed at his own pace. This has the added advantage of allowing the better student to proceed at a faster rate (usually on independent study).

The consensus that developed on the topics to be treated and considered essential in a chemistry course for nurses placed slightly more emphasis on inorganic and organic chemistry than on biological chemistry. While the nursing educators express a preference for greater emphasis on biological chemistry, the chemical educators felt that, because of the limited time for teaching this course, it was necessary to spend more time on inorganic and organic chemistry for purposes of review and to give the student a broader foundation before tackling biological chemistry. With the active cooperation of the other teachers in the nursing program, the applications of biological chemistry can be shown in the other science courses. However, when examining the topics themselves in relation to a one-semester course specifically aimed at what a nurse needs to know, there are a number of traditional topics in organic and inorganic chemistry that could be eliminated or very drastically reduced in their discussion, as for example the modern theories of chemical bonding or the exhaustive analysis of the reactions of each of the organic functional groups. Indeed, this latter topic can be very effectively interwoven in the discussion of biological chemistry.

Some concern was expressed about the transferability of such a course, should a student choose to subsequently enroll in a baccalaureate program. Transferability is granted *only* by the institution to which a student applies and is usually judged in the overall context of the student's performance in all courses, as well as past experiences with graduates of that two-year college. It does appear that there are four-year colleges that would accept such a course as proposed herein. The emphasis in planning this course should be on the knowledge needs of the students and *not* on whether or not the course will be transferable for the small percentage of students which elects to do so. Some descriptive as well as relevant material must be retained to prevent this course from becoming a dull recitation of abstract theories.

The depth of presentation of material was a very important matter of discussion. Most textbooks, even those for students of the health sciences, seem to have been constructed with the traditional, two-semester course in mind. Of course, the four-year programs, where greater depth is expected of the students, could afford to teach this subject matter in two semesters.

2. *High School Chemistry or Its Equivalent be a Requirement for Admission to a Nursing Program.*

Prior to the recent development of extensive networks of two-year community colleges, registered nurses received their basic education in traditional, four-year institutions or in hospital schools of nursing. In both cases, the background of the students was reasonably homogeneous - recent high school graduates whose prerequisites for admission included one or more sciences and mathematics through algebra. With the advent of the community colleges, the background of those entering nursing became more varied than before. Students may come directly from high school or they may be under-employed LPN's, or they may be housewives who have not been to school for ten or more years. Such a heterogeneous group cannot be brought together and taught in the same manner with the same results expected. The educational background of those entering from high school is also varied, as the underlying philosophy of the community colleges is to accept all those with high school diplomas or the equivalent.

That a minimum of entrance requirements exists for admission to a community college does *not* preclude the establishment of specific prerequisites for admission to specific programs within the community college. It was therefore strongly urged that, in order for the science courses for nurses to have any meaning, minimum prerequisites of a high school biology and a high school chemistry course be set, and that entering students should also have completed high school algebra. Without prior acquaintance with the sciences, the students will have much difficulty understanding the concepts and language of chemistry, especially when taught in a one-semester course.

If the student does not meet this entering criteria, he should be enrolled in a pre-nursing program, possibly offered in the summer session preceding the usual fall enrollment. The chemistry in this pre-nursing program should include an introduction to inorganic, organic, and "life" chemistry with emphasis on the language and conceptual developments.

The use of pre-test placement of all students should be encouraged. There are many older students who technically meet the prerequisites but have been away from school for some length of time. A pre-test properly interpreted, can measure the student's ability to succeed in a specific subject area regardless of his "on paper" qualifications.

While much has been said about properly preparing a nursing student for this course, and many strong suggestions were made on the use of learning aids to assist the student in his comprehension of chemistry, one should not equate this with the premise that all who enter the course must pass - and neither should the student be passed "just because she would make a good nurse." Poor performance in chemistry may not affect her ability to be a "good nurse" but it would have a very grave effect on her ability to function as a *safe nurse.* Chemistry in this course is too fundamental in application to the other sciences for it to be passed over lightly.

3. *That Chemistry Take Precedence Over Physics or Physical Science in the Nursing Curriculum.*

Chemistry is a study of the interactions and alterations of matter and, as such, forms the basis for understanding the other natural sciences. At its most elementary level, life is nothing more than a series of carefully programmed and highly intricate chemical reactions. The understanding of chemistry provides the background for understanding the body in health and disease. Therefore, it is essential that a nurse be taught chemistry in preference to the other sciences if there is a time factor. Further, the chemistry must be taught in the first year, preferably in the first semester, so that it can be applied to other science courses and to the nurse's clinical practice.

Questions have arisen on the inclusion of physics in the one-term course in chemistry. This would result in a general education, physical science course which would have both advantages and disadvantages. There is usually sufficient physics in the form of the gas laws and thermo-chemistry to satisfy the needs of the nursing student. Other topics such as levers, internal combustion engines, center of gravity, etc., can be treated in a simple, descriptive manner.

Within limits, there will be an overlapping of subject matter of certain areas in chemistry with the content of such courses as anatomy and physiology, microbiology, nutrition, etc. Not only does the see these concepts from a different viewpoint - but this will also provide reinforcement of the previous learning. It will also illustrate the practical application of the often-abstract ideas of chemistry.

4. *Creation of an Advisory Board.*

Chemistry is a dynamic subject, constantly undergoing change not only in content but in manner of presentation. An advisory board to act between the chemistry department and the nursing department at the academic level is necessary for a number of reasons: first, to advise the nursing educators, as well as the other science teachers, of changes in course content particularly as our knowledge expands. Second, the advisory board helps the chemist in providing vital communication as to what the nurse needs to know in order to do a more effective and safer job. The board could also audit courses and recommend changes, additions, etc., in the application of chemistry to nursing. This is particularly important as a new chemist is assigned to teach the course. The professional training of chemists normally concentrates on the broad principles from an almost theoretical and abstract point of view, while the course designed for community colleges is subject-oriented towards particular applications. Therefore, the faculty member assigned to the course must be made aware of the needs of his students and how his material will fit into subsequent courses in the nursing curriculum as well as into the nurse's professional activities.

At higher levels the advisory board can function in much the same manner: to serve as a means of communicating to the nursing profession changes that are taking place in the content and method of teaching chemistry, as well as to learn how the chemistry already taught is being applied (or misapplied). This board could also unify the quality of the chemistry offering of the various colleges involved in the education of nurses by suggesting certain guidelines or syllabus that might be followed.

5. *Future Plans.*

Of immediate interest is the development of a fairly general syllabus that a one-semester course in chemistry for nurses should include. It is natural that individual instructors would want considerable freedom in tailoring their course to their own interests, so the syllabus should allow the individual to choose his own text and pace the course according to the background of his students. Accompanying the syllabus should be a guide to audio-visual-tutorial materials that could be used to supplement the textual and lecture presentations. A number of these already exist, but their sources are frequently so diverse that the individual teacher, especially one at a smaller school, does not have access to all of them.

PROBLEM SOLVING IN BEGINNING CHEMISTRY COURSES

Mildred Johnson
City College of San Francisco, San Francisco, California

Presented at the Beginning Chemistry Course Section, 20th Two-Year
College Chemistry Conference, Fullerton, October 4, 1969.

Let me give you some of the background about the "problem solving" approach we use at the City College of San Francisco. We have 20,000 students with an extremely broad spectrum of ability. Some have a very low native intelligence. Some very intelligent students have very poor backgrounds. We also get some extraordinarily good students; for example, in one chemistry majors organic class, I had a lab section in which half the class have gone on to study for Ph.D.'s.

To screen students for Chem 1A, City College uses Parts 2 and 4 of the SCAT test, which supposedly measure quantitative thinking. If the student scores 5 or more (which is about the 60th percentile and up), he gets into Chem 1A. We have had good results with this screening.

Other good students are placed in a course called Chemistry G17 that is not chemistry at all, but a problem solving course. It might be called remedial but it is remedial only in the sense that it fills in what they should have gotten earlier. It is not remedial in the sense of being for students who are low in native ability. We do not drill on arithmetic of any sort. If the student needs to learn to do decimals and things of that sort, he belongs in an arithmetic class. And if he hasn't had algebra, he belongs in an algebra class. A student who has forgotten how to divide decimal numbers picks it up quickly while working with problems starting out with something called "comparison and correction." For example, we might ask, "What's the volume of X quantity of gas at Y and Z conditions?" He might answer, or start answering, "1 over 250 liters," or something. We then guide him by questioning, "What are you looking for? If you are looking for volume, operate on volume." He then starts getting the sense of whatever it is that is going to change this. In other words, use a base element in a correcting factor method. Students seem to enjoy this approach and they seem to profit from it. It is something that can be used in traditional chemistry calculations such as moles, gas law problems, colligative properties problems, etc.

We try to stress finding the nature of relationships so that they know how things change -- and the effect of changes -- never to think about multiplying or dividing, but rather what the effect is. These students' chief problem is that they are weak in mathematics so they are reluctant to discard methods they already have memorized how to use. We have made up problems that are completely unreal, absurd and unreasonable. An example is asking how long it will take a student to learn X words if the rate of learning words is inversely proportional to the time spent studying. He cannot do the problem unless he uses the method we are trying to teach him. Sometimes we have a teacher who would like to use chemistry problems or science problems. This might be very good, but using a science problem or a chemistry problem means simultaneously coping with two problems: the problem solving and the subject matter of the chemistry. The teacher's energy is concentrated if he uses non-science problems and, especially if they are unreal ones, the business of using memorized methods is avoided and embroilment in physical facts is prevented.

We then undertake to do problem solving by analogy. A student who can cope with problems in feet and inches is stuck with centimeters and angstroms. We do a number of problems with British gallons and bushels and things of this sort. We go from one unit to another to another using something he has not seen so that he must reason it out. Then he can use his knowledge that 1 foot equals 12 inches as an analogy. For an unknown reason, students seem to think this is not a good method to use. We also stress looking for the sense of operation and whether an increase or a decrease should be expected. This is the kind of thing we have done and we have had success with it.

We stress careful reading of problems. We start with simple, directly-worded problems and then go on to problems which are expressed in a complex fashion, or are worded deliberately in poor fashion or are filled with excess, irrelevant information because this is the kind of thing they are going to have to sort out and find out what they would use in something like 1A.

We stress "dimensional analysis." We have had much trouble getting the student to always use units and to sense where the unit is. Students must measure the density of a piece of aluminum as an exercise in Chem G17. Some may end up with an answer with units of g^2 ml. They go through many operations and end up with a grand mess.

We stress getting the students to ask questions; to ask questions and tear problems apart and go on.

After we have done the "comparison, correction and analogy" and "sense of operations and unit analysis," we work in things like powers of ten, logarithms and things of this sort to give them working tools.

After these things have been done, I particularly like taking a section on algebra, that is not algebraic mechanics. Instead, I give them a problem to put into symbolic form. The problem is not solving the equation once they get it; the problem is putting it into symbol form. Students have trouble putting things into algebraic symbolism and that is the most basic kind of symbolism. I like to go through all sorts of algebra arrangements with no thought of really solving the problem when we get through. Once they get the equation, they can solve it.

After this work, we go through the standard things expected of students going into Chemistry 1A after having had high school chemistry. We use the concept, a little thermochemistry, equilibrium and some other similar topics as time permits.

We have been testing the results of this approach. Four years ago, two instructors had this course all to themselves, myself and another instructor who had been teaching for a number of years. We did very much the same thing and we found that our students that went into Chem 1A had very little chance of getting an A or a B and very little chance of getting a D, F or a Drop. They were solidly 'C.' Even though they were screened, 40% of our regular students dropped out or got a D or an F.

We made a study at the end of a spring semester. When there were a total of 5 instructors teaching the course, 3 of whom were brand new to the school and two of whom had never taught before, we found that our results worsened. We found that we still did not get A's and B's. The percentage of D's and F's was the same as for the regular students in Chem 1A. There was still a lower percentage of Drops, and a much higher percentage of C's than the regular Chem 1A.

CHEMICAL TECHNOLOGY COURSES CONTENT AND CURRICULA

CHEMISTRY FOR TECHNICIANS AT LOS ANGELES VALLEY COLLEGE

Joseph Nordmann
Los Angeles Valley College, Van Nuys, California

Presented to the Chemical Technology Programs Section, 20th Two-Year College Chemistry Conference, Fullerton, October 4, 1969.

In my limited experience of teaching chemistry for technicians, I think we have learned what some of the problems are in recruiting technology students. The students that we get in our course are really in electronics and mechanical drafting technology. We give them a one-semester service course in chemistry called the Chemistry of Materials. We try to bring in such things as electroplating and chemistry of metals. Electronics technology graduates have no trouble getting jobs–in fact we often have several companies bidding for one graduate. Despite the fact that we have industries that will take anybody that we can graduate from the two-year program, we have great difficulty in recruiting students for technology.

I hate to tell you how we get technology students. When you have a large liberal arts program and almost 20,000 students registered at your college, you have a huge catalog of courses and a regular smorgasbord selection results. With the exception of surf casting and skin diving, the course offerings are nearly unlimited. With this sort of situation, nobody is interested in technology. You can promise them jobs; you can tell them that they will never make up the time spent in school if they go on to a "very average" Bachelor's Degree; and you can point out the money lost in two years of studying. They will still go into the liberal arts courses.

Every student takes an entrance exam of a general intelligence type and the scores are recorded on IBM cards along with his preference of program. If someone does poorly on this entrance exam and yet he says that he wants to do anything whatsoever in engineering or physical science, his card is sorted out and a counselor talks to him. Typical advice is of the sort, "Now, look. You want to get into physical science, engineering, or something related and the entrance exam says that you can't make it. We're going to recommend that you get into technology." And you hear everything but arms and legs snapping in those counseling offices as counselors try to convince these people that they should be technologists because they can't possibly make it in engineering. They say, "Take the technology course and if you can work your way out by virtue of getting high grades, maybe taking one other outside academic course like English 1, and showing that you are one of these late bloomers or that you've been under a rock waiting to be discovered, then we will put you into the regular engineering course or physics major or whatever you thought you wanted to study." This is the kind of person that we are getting in technology. Well, the person comes in with a somewhat bad attitude and now you have to reorient him and show him that technology is a good deal. They do quite a good job in electronics technology and we have tried to support that program. But as soon as we try to get theoretical in chemistry–and you just can't teach chemistry on an empirical basis–a glaze settles over the eyes of the class. You all know what it is. You simply are not getting that material through. You lose them immediately. Therefore, you have to have some real experiences to relate to the course. You've got to show the students that this material's meaningful every step of the way, that it is related to what they are going to do. This is particularly true in the laboratory.

I have been around the country and talked to people teaching technology courses and to technicians in industry, and nobody has the answer on how to recruit technology students. After having thought about this for several years, I am convinced that there are two ways to recruit technology students. One way is to have a school system in which technology is the only thing that is offered; there are some places like that in the country. However, California has a junior college practically within walking distance of everyone who wants to go to school and these colleges have great liberal arts programs. That completely defeats technology. With this situation students are not going to enter technology. In the East where education is not nearly as cheap, some places may have two or three schools in a fairly large city. One of them is a Catholic university, another is a state university with high standards and the other is a technical junior college. There you can fill up technical programs.

The other way that technologists can be recruited (and I think this should be the policy all over the United States) is for the industries in a given area to get together and say, "We want some technologists," and then do something about it. There are then several large industries who together can employ some ten or more technologists. They can survey their plants and see who's working on the loading dock with a dolly and shoving boxes into a box cart; they're apt to find a guy who looks brighter than his plain manual job, who shows some ambition and yet is forced to work because of a wife and children. Industries can offer to pay these ambitious people to go to school for a few hours a day; or they can pay them to take an evening course. Industry can coordinate its program with local junior colleges, give the school some used equipment or even send over an instructor at night and help set up a college chem tech program. These students are people who are working and are feeling the economic press; these are the best people that you can get. I've had personnel in industry tell me this: the best technician that you can possibly get is a man with an I.Q. of 110 who is trying to buy a home, some furniture, an automobile and he's married and has a child. Here's a person who is bright enough to do the job, he's got economic pressure on him and he's got to work. He can't goof around in school changing majors. He can't waste time. Industries are looking for this type of person; they already have this type of person working in the plant. The person is motivated and he has already shown that he wants to work. If industry would send us these people, we would have a terrific technology class, not because they would be the brightest students, but because they are motivated. People who simply want to be rewarded for doing the job are the greatest technology students. Industries which send employees to school can say, "We've helped the college plan these courses and we'll give you a raise in pay if you complete the program. In fact, we will give you a raise while you are studying and showing progress. This will give you the opportunity to work in the laboratory and move up in the company." You have outlined a career in technology for this man.

In the experience of Valley College and various other schools I have talked to, you cannot drag people off the asphalt and say, "Now look. We would like to see you be a technologist. Here is the program that we have outlined." That's doing the thing backwards. It's a long sales job and many of the people will not stay with the program. Industry must provide the students.

Once you have the students, the problem is keeping them. I would like to mention something we didn't do in our planning for the Chemical Technician's Curriculum Project last summer (1969). We said that our first objective was to teach lab techniques and that the program would be heavily lab-oriented. But what we put down on paper was an outline for a series of textbooks. We have to integrate those textbooks so that they are textbook lab manuals. We really didn't say what "laboratory" consisted of. I am a strong believer in samples and experiments in the laboratory which have relevancy to what technicians are doing. In my experience you have to sell students every day on the need to be a technician and the use of technicians in industry. That means applying all the lecture material and at least once during the hour saying, "Here's where this applies." Most teachers have limited knowledge of the chemical industry so the problem comes up of trying to put real experiments in the laboratory. How do you do this? I don't think that you can put in the regular academic experiments. The student simply does not see any relevancy in those. He may not know anything about chemistry, but he feels instinctively that that just isn't real, that it doesn't apply to what he is going to do. If a teacher can draw from experience, that's fine; but if he can't, he needs to do something else to come up with these experiments.

I think that the person teaching technology needs to know the industries around him and know some of the chemists and technicians as well. He may have former students working in such positions. But if he's a new teacher, he has to work up these contacts. He has to find out what technicians are doing; he has to talk to laboratory technicians and learn some of their laboratory methods. Most industries are very receptive. Let them know you want to help them and that you need their help. Get copies of their laboratory experiments. There aren't many laboratory techniques that are trade secrets. I've found great cooperation and acquired a file full of material in this manner. One laboratory sent me a book of their laboratory methods that normally costs $75. Build up personal friendships, and industry will bend over backwards to help you. They love to have teachers view their laboratories.

Sometimes you will be amazed at just what these laboratories are doing. Some people think gas chromatography is over the heads of these technicians, but gas chromatography is one of the techniques that a technician simply has to have. Shell Chemical has a laboratory with 26 gas chromatographs; they have three shifts of technicians and those gas chromatographs are running 24 hours a day. You simply have to teach the principles of gas chromatography; *you simply have to have a gas chromatograph* in the laboratory so that students get some experience using it. Find out the techniques of local industries and adapt them to your laboratory. Some techniques are beyond what your technicians might be doing or the samples used might be specific to a certain industry, but you can find in their experiments the principles that are important.

There are a variety of samples that can be used in the laboratory which are very interesting and relevant to these students. I've used some of the same samples and some of the same techniques in quantitative analysis as those used in industry. This semester I am teaching a course in quantitative analysis. One of the things that you usually do if you are teaching quantitative analysis is a precipitation titration, often titrating fluoride with silver. I have people who think they are going to be oceanographers; so I have them bring in sea water to analyze for chloride. It takes no time at all. Take several 5 milliliter samples of sea water, dilute them and titrate them with silver. For students with a biological orientation, I have them titrate the chloride in their own urine. The sample's already in solution so that they can just take a 10 milliliter or 5 milliliter sample.

As I view it, there are two basic problems if you are just starting a chemical technology course. The first is recruiting technology students. Industry must be made to send employees for training and offer other assistance. The second is that the laboratory must be made relevant. Using industrial samples and techniques whenever you can is a step in this direction.

ADVANCED EDUCATION IN CHEMICAL TECHNOLOGY

G. William Lawless
University of Dayton, Dayton, Ohio

Presented at the Chemical Technology Section at the 22nd Two-Year College Chemistry Conference, Columbus, June 8, 1970.

Post-Associate Degree education is becoming more widely available. The University of Dayton began offering a Bachelor of Technology Degree in 1965 which is open to graduates of the Associate Degree programs. In Dayton's case, the additional time may be used to broaden an individual's technical background as well as provide additional education in chemistry and/or chemical engineering.

The requirements for the B.T. Degree (after the Associate Degree has been earned) are much more flexible than for the Associate Degree program. The following tables demonstrate the flexibility by describing the requirements for both the Associate Degree and the Bachelor of Technology Degree at the University of Dayton.

Associate Degree in Chemical Technology

First Year

			Class Hours	*Lab Hours*	*Credit Hours*
First Quarter					
General Chemistry	CTI	122	3	3	4
Technical Institute Mathematics	STI	105	3	0	3
English: Language and Thought	Eng	101	3	0	3

First Quarter (cont.)			*Class Hours*	*Lab Hours*	*Credit Hours*
Philosophy: Basic Problems in	Phl	106	3	0	3
Introduction to Engineering Technology	STI	150	1	0	1
Theology or Elective	Thl	112	3	0	0
			16	3	17
Second Quarter					
Inorganic Chemistry	CTI	125	3	3	4
Technical Institute Mathematics	STI	106	3	0	3
Technical Drawing	MTI	103L	0	6	2
Physics: Mechanics	STI	114	2	2	2-½
Effective Speaking	STI	134	2	0	2
Industrial Organization and Production	ITI	101	3	0	3
			13	11	16-½
	Second Year				
First Term					
Quantitative Analysis	CTI	202	3	6	5
Organic Chemistry	CTI	208	3	3	4
Elements of Supervisior	ITI	203	2	0	2
Physics: Heat, Light & Sound	STI	214	2	2	2-½
Theology or Elective	Thl	----	3	0	3
			13	11	16-½
Second Term					
Organic Chemistry	CTI	209	3	3	4
Instrumentation	CTI	206	3	0	3
Physical Chemistry	CTI	203	3	3	4
Physics: Electricity	STI	213	2	2	2-½
American Political Ideas	STI	252	3	0	3
			14	8	16-½
	Third Year				
First Term					
Chemical Engineering Technology Calculations	CTI	309	3	0	3
Chemical Engineering Technology	CTI	308	2	3	3
Materials Science	CTI	305	3	0	3
Philosophy: Basic Problems in	Phl	206	3	0	3
Report Writing	STI	234	2	0	2
Economics of Industry	STI	251	3	0	3
			16	3	17

Second Term

Can continue to Bachelor of Technology

Bachelor of Technology Degree

4 Years, 128 Credit Hours, University of Dayton

Academic Requirements

Prerequisite: Associate Degree (Based upon the 2-½ year program at University of Dayton)

6 Credit hours	English
3 Credit hours	Mathematics
1 Credit hour	Seminar
3 Credit hours	Psychology
3 Credit hours	General Electives
9 Credit hours	Humanistics-Social Electives (e.g., English, Economics, Philosophy, History, etc.)
21 Credit hours	Technical Electives (selected from such areas as electronic industrial and mechanical engineering technologies, chemistry computer science, biology, geology, mathematics, etc.)

46 Credit hours - total

Credit Hours and Subject Area Comparison of B. T. Degree with B. S. in Science or Engineering

Subject Area	*Bachelor of Science Degree*		*Bachelor of Technology*
	Chemistry	*Chemical Engineering*	*(Typical for Chemical)*
Chemistry	51	23	31
Chemical Engineering	---	33	12
Math and Physics	27	27	17
Add. Tech.	---	19	23
Non-Tech.	48	29	45
Total Hours	126	131	128

Industrial Reaction to Advanced Training in Chemical Technology

Gerald Lea Chemical Technologist
Education: 2 year associate degree from University of Akron.
Fifteen years of laboratory experience.
Would like to take four-year program in technology using present credits in chemical technology as part of his degree.

Suggested that chemical technology programs be advertised to people already in the field.
Criticized the two-year chemical technology program as inadequate because too much emphasis is put on theory and not enough on practical applications.
Suggested that industrial chemists should help write textbooks.

Richard Henricksen Chemical Technologist
Graduate of Cleveland Technical School (2-year course)
Criticized the advertising on the chemical technology program and felt that it should be wider than just high school students.
Was undertrained in practice, overtrained in theory and criticized the textbooks used.
Criticized colleges for not accepting technology courses for credit in four-year degrees. Will be learning chemical technology field for business administration.

William Bissinger Chemist
Believes that the two-year chemical technologist should be a specialist to make the most of the program.
Does not see underprivileged people taking advantage of chemical technology program.
Urged better attitudes from chemical technology people new in the field.
Suggested schools use industrial chemists to lecture to chemical technology students.
Suggested that we would work for improved status for chemical technologists in the scientific community.

Robert Imhoff Personnel Officer
There is still a great need for graduates from chemical technology programs. Many of their jobs are filled from people hired off the street.
Tuition refunds are offered chemical technologists who desire to continue education.
They like the two-year chemical technology program and then continued education after working a period of time.

General Conclusions:

1. Chemical Technology students would like longer (4-year) programs which would go more into practical aspects of chemical technology.
2. Industry is generally satisfied with the two-year program, mainly because there seems to be a shortage of trained technicians.
3. The role of the chemical technology graduate in the industrial and scientific scene is nebulous. He is often in competition for jobs with B. S. graduates. It is difficult to reward him when he is valuable as an engineer.
4. Everyone seems to agree that specialization is good for the chemical technology graduate, but it is difficult to know what to specialize in in a two-year program, and generally the specialties are not defined.

INSTRUCTIONAL METHODS IN CHEMISTRY

THE USE OF A SMALL DESK-TOP COMPUTER IN THE BEGINNING CHEMISTRY LABORATORY

William T. Mooney, Jr.
El Camino College, Torrance, California

Presented at the Symposium on Innovations at the 20th
Two-Year College Conference, Fullerton, October 3, 1969.

This is a report on experiences in developing a program for the utilization of a small desk-top computer in the laboratory portion of the beginning chemistry courses at El Camino College.

The question has been posed, "Why should one use a desk-top computer in a beginning chemistry laboratory program?" I answer such questioners by pointing out that the inclusion of such a technique can bring about four significant improvements:

1. The improvement of student performance on quantitative experiments.
2. The improvement of the instructor's evaluation of student laboratory work.
3. The improvement of laboratory procedures and unknowns.
4. The improvement of student logic in the solution of problems.

To better understand the chemistry laboratory as an instructional process and to better explain the way in which the computer has been utilized, a four-stage input-output model has been developed. All input-output models have four major characteristics. (1) Input which includes all that which flows into the main processing unit; (2) the processor, which converts the input into output; (3) output, which includes all that which flows out of the processor; and (4) feedback, or the output which is used directly or in a slightly altered version as input for the next cycle through the processing unit.

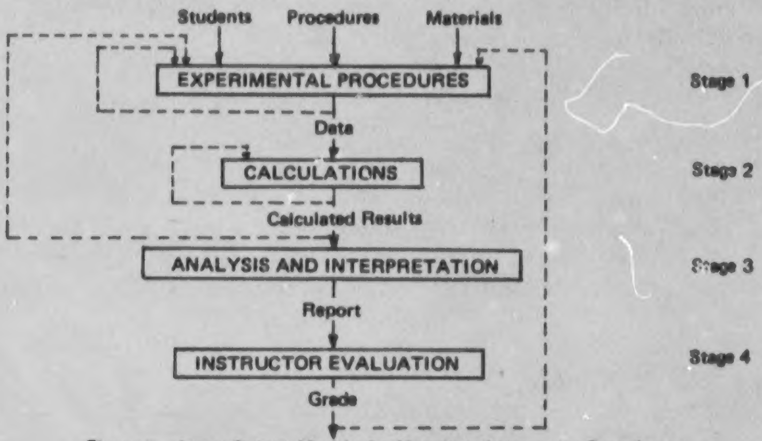

Figure 1: Input-Output Model of a Chemistry Laboratory Experiment

Input-Output Model of a Chemistry Laboratory Experiment

The stage 1 input includes students, procedures and materials. The processor involves the student performing the experiment using the input materials according to the procedures suggested to him. The output is the student-recorded data, which might be either quantitative measurements or simple observations.

Since the four stages of the overall model are arranged in series, the output of the first stage, the data, is in reality one of the inputs of the second stage.

The feedback takes off from the output flow line and loops back into the experimental procedures block as an input flow line. This represents the evaluation which the student and instructor, conferring about his results, make on his first trial of a given experiment before he starts his second trial. Hopefully this provides new information which will influence the work of the student on subsequent trials; therefore, it represents input for his later runs through the experiment.

In the second stage the data input from the first stage flows into the processor entitled "calculations." This involves all of the calculations the student makes in working up the data from his experimental work. The output is the calculated result of the experiment and this flows sequentially into the third stage as input for the analysis and interpretation. It may also serve as feedback for either the experimental procedure process or the calculation process on later trials.

The third stage, "analysis and interpretation," uses as input the calculated results from the second stage. The student analyzes and interprets these results in the third process and generates a student report on the experiment as output.

The student reports become the input into the fourth stage in which the instructor evaluates the reports and assigns grade, the output, for this student's laboratory work. An additional output of the instructor's evaluation of the individual reports in his analysis of all the reports he receives wherein he may generate significant new information about the experiment and student performance. This can be fed into the experimental procedure process the next time he has a group of students doing the same experiment. This could be that afternoon, the next day or the next term. This new input may improve the experimental work of the later group.

In our beginning chemistry laboratory classes, the computer has been utilized as a method of getting quickly from the completion of the process in the first stage, experimental procedures, to the output of the second stage, calculated results, soon enough so that we have significant feedback for the student during his laboratory period to influence his work on later trials.

It is not my intention to describe, in detail, the computer, how it is programmed, how it operates, its program language, or any other details of it as a computer. Anyone sufficiently interested in the application of the computer in an instructional situation may find the answers to questions in such areas in information supplied by the manufacturer. It does not take much time to go through these materials and learn how to use such a computer in the simpler modes of operation.

There are several characteristics of the Olivetti Programma P101 which we use which make it useful for our application in the beginning chemistry laboratory program. Those found to be most useful include the following:

1. The ability to store a 120 step program on a magnetic card which is merely inserted into the machine to put a program from your program library into storage for immediate use.
2. The paper tape printout of all input data and of any output which you have programmed for printout.
3. The compactness, portability and ability to operate in any reasonable environment.
4. The simplicity of programming.
5. The directness of data input which is entered directly on the keyboard and does not require the preparation of cards or tapes.
6. The directly programmable mathematical operations of addition, subtraction, multiplication, division and square root.

I must also mention some of the limitations and unfavorable characteristics which have been found with the Programma. This list includes those items which prevent us from doing something we would like to do or that have "bugged" us about Programma.

1. There is no alphabetic capability, only numeric, thus requiring the use of many numeric codes for identification, etc.
2. The processor unit truncates numbers in performing various mathematical operations which requires one to carry through several additional decimal places in calculations. This also causes small deviations from student calculated data, generally in the last significant figure, or the estimated digit, which would not be so if the computer were capable of "rounding off" numbers rather than truncating them.
3. The machine is noisy when it operates. The noise is of a continual background type rather than of such character as to interfere with discussion with the student. There is available a silencer for the machine but we have not felt the cost of the silencer was low enough to justify it for our operation. Recent models have corrected this.

4. The inability to wipe out erroneous input data once it has been transferred from the keyboard input into the entry register.
5. The inability to store reference tables of information.
6. The time required to complete problems with many items of input data, or many samples, and which require many calculations and data movement steps.

Programs for the Programma computer have been developed and used for each of the laboratory experiments in our beginning chemistry course that require calculations. These programs use the student's experimental data as input and perform all of the necessary calculations required of the student, including percentage error. Printout data is programmed so that it coincides in order with that requested in the student's data table.

Specific experiments for which programs have been developed are the following:

1. Titration of an unknown base (acid) with a standard acid (base).
2. Density of a solid.
3. Percentage of water in an unknown hydrate.
4. Percentage of oxygen in potassium chlorate, recovery of the manganese dioxide catalyst, and the molal volume of oxygen.
5. Weight of 1 equivalent of magnesium.
6. Charles' Law and Absolute Zero.
7. Heat of neutralization.

These programs are used to perform the student calculations immediately after he has completed taking data, and before he has proceeded to additional trials or to making calculations. This procedure gives the student immediate feedback about his results (i.e., high, low, or acceptable) so that he may improve his technique for the later trials.

The programs have also been used to check calculations, on at least one trial of the experiment, before the student leaves the laboratory. This is done to give the student immediate feedback about his calculations so that he will know if he is on the right track and where his errors are and what kind of errors they are.

The third use is to check all student calculations when grading the experiments. This is done because beginning chemistry students are prone to make many mathematical errors. This allows an evaluation of the laboratory work and their calculations. Note that this allows the instructor to evaluate the laboratory work separately from the calculations if he so desires.

The final use has been to summarize student performance on the experiments and unknowns in terms of average class or unknown values and deviations from the accepted values. This allows us to evaluate the adequacy of the experimental procedures and the modifications we make from time to time. It is also done to determine "norms" for evaluating student performance on a given experiment or unknown.

In addition to these laboratory programs additional programs have been developed for the mathematical solution of certain general or specific types of chemical problems, assuming a certain logic to be followed for such solutions. Among programs of this type the following have been developed:

1. Chemical calculations problems utilizing the unit conversion or factor-label method. This includes calculations from chemical equations, measurement conversions, mass or volume determination of a sample, amount of solute in a sample, etc.
2. Dilution problems.
3. Determination of the formula from experimental data.

Additional programs have been developed for making the various types of computations and calculations associated with grading and evaluation of laboratory reports, quizzes, tests and overall student work. These include the following:

1. The percentage of total possible points.
2. The percentage of total possible points when absences are involved.
3. The deviation of performance on one test from course performance and the evaluation of a suggested scaling factor.

4. The sum of the scores and the mean score for a group on a test.
5. The mean, standard deviation and standard error of the mean for a distribution of results.
6. Determination of percentage error.

In summary, I have found that the use of one small desk-top computer has resulted in a significant improvement in the laboratory instructional program in the beginning chemistry course. It has been adequate for all of the major uses which I have attempted or can envision for this course at the present time. There are at least three other computers of this type commercially available and I would recommend that before deciding on any particular model that a faculty make a careful analysis of the requirements of their applications and attempt to match the characteristics of the computers to these requirements.

INTRODUCTORY CHEMISTRY AT ST. PETERSBURG JUNIOR COLLEGE: AN INDEPENDENT STUDY COURSE

Arthur W. Gay
St. Petersburg Junior College, St. Petersburg, Florida

Invited paper prepared for *Chemistry in the Two-Year College,*

Purposes and Prequired Performance

I. The three purposes of this course
   A. This course prepares students for enrollment in CY 155 Chemical Calculations.
   B. This course serves to meet chemistry requirements for those enrolled in health-related programs.
   C. This course serves to meet, in part, the general education requirements in science.

II. What is expected of the student
   The student is to demonstrate his readiness for CY 155 by making acceptable performance scores on qualifying tests covering selected terms, chemical procedures, chemical principles, and simplified theories of the structure of matter.

General Instructions

This course allows each student to proceed through the program of activities at his own rate; well-prepared and highly interested students may even complete an advanced program during this session; others may find it necessary to complete some of the basic work after the end of the session. The final grade will depend not upon the time spent but upon the student's meeting designated performance levels.

The assigned activities of this course include the use of texts, classroom lecture-demonstrations, seminars, taped lectures (both audio and video), films, laboratory experiments, student-teacher conferences and a sequence of tests which the student must complete by demonstrating a specified level of proficiency on each test.

Required Tests and Materials

Arthur W. Gay, *Study Guide for CY 150-151 Introductory Chemistry* (St. Petersburg Junior College, St. Petersburg, Fla., 1971).

Virginia Powell, *Programmed Unit in Chemistry* (5 volumes), *Chemical Symbols, Chemical Formulas and Names, Molecular Weight Calculations, Weight and Volume Calculations, Balancing Chemical Equations* (Prentice-Hall, Inc., Englewood Cliffs, N. J., 1965).

For Dental Hygiene students only:

Jack E. Fernandez, *Modern Chemical Science* (The MacMillan Company, New York, 1971).

For all other students:

Russell H. Johnson and Ernest Grunwald, *Atoms, Molecules and Chemical Change* (Prentice-Hall, Inc., Englewood Cliffs, N. J., 1971).

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* Most of these items may be purchased at the Bookstore.

*Programmed Texts Available from Independent Study Materials Center**

R. J. Flexer and A. S. Flexer (Harper and Row, Publishers, New York, 1967).

Renee Ford, *Gases, Vol. 1 Gas Laws* (Holt, Rinehart and Winston, Inc., New York, 1962).

Renee Ford, *Gases, Vol. 2 Kinetic-Molecular Theory* (Holt, Rinehart and Winston, Inc., New York, 1963).

G. I. Sackheim, *Chemical Calculations Volumes A and B* (Stipes Publishing Co., Champaign, Ill., 1962).

Jay A. Young, *Arithmetic for Science Students* (Prentice-Hall, Inc., Englewood Cliffs, N. J., 1968).

Jay A. Young, *Chemical Concepts* (Prentice-Hall, Inc., Englewood Cliffs, N. J., 1963).

Lecture-Demonstrations

Lecture-demonstrations are used to present selected aspects of chemistry which lend themselves to this type of learning situation. The informal presentations will at times allow student participation. Lecture-demonstrations will be given during the large group meetings held once each week in the teaching auditorium.

Seminars

As a rule students will meet once each week in groups of ten for a twenty-five minute period. At this time each student will have an opportunity to orally meet selected performance objectives relative to laboratory work or lecture demonstration material covered in the previous week. Scores assigned will consider attendance, quality of performance, and contributions to the seminar discussion. Members of the Chemistry Faculty will conduct the seminars.

Taped Lectures

Audio tapes cover introductory material and selected concepts. Cassettes for the several topics may be checked from the Independent Study Materials Center for use in the laboratory carrels. Copies of these tapes will also be available at the College Library. Guides to tapes are supplied in the *Study Guide for CY 150-151 Introductory Chemistry with Laboratory.*

Video tapes covering these topics are being prepared. Showing of these tapes will be arranged on a schedule fitting with that of the Television Department. The Television Department may be able to meet a limited number of requests by individuals or groups for special showings.

Film Loops

A library of over 100 film loop titles dealing with practice and theory of physics and chemistry is located in the Independent Study Materials Center. The student may check these film loops for use in the laboratory carrels equipped with super-8 projectors. The student is expected to view all titles listed as part of his program; however, he need not limit his viewing to these titles; he is welcome to supplement his program with any of the titles he believes to be helpful.

When available, duplicates of the assigned titles will be available in the College Library.

Laboratory

The laboratory, Sc. 107, consists of 18 stations each equipped with a laboratory bench and a study carrel. A hood and a bench for special experiments is located on the north wall. The aisle along the window wall is furnished with a small library of chemistry texts and serves as a browsing and study area. The southern portion of the room is used for testing, seminars, and student-instructor conferences.

Although the laboratory will be open at all times for use of unassigned carrels and other study areas, students will not be allowed to conduct experiments except when the laboratory is staffed by a member of the Chemistry Faculty.

At the northwest corner of the laboratory is the Independent Study Materials Center from which various learning materials may be obtained. Normal library rules are followed. The center is staffed by students during the hours it is open; these hours will be posted. Responsibility for items obtained from the center lies with the students signing for the items. Students failing to return items when they are due are subject to the normal library fines.

The office of the program director is located in the northeast corner of the laboratory. Students are encouraged to discuss the various aspects of this multi-media approach to chemistry with the director.

Student-Instructor Conferences

Members of the Chemistry Faculty will be supervising all scheduled laboratory periods as well as a few unscheduled hours. The instructors will use this time for assisting students having difficulty in their work and for administering the testing program. Although students needing assistance should first seek help from the laboratory instructor to whom they are assigned, if their difficulty continues they are free to contact other members of the Chemistry Faculty as opportunity permits. This program recognizes that some student-faculty relationships are more effective than others and that contact with several instructors is of value to the students.

Testing Program

In order to determine the mathematical ability and the chemistry background each student brings to this course, a pretest is administered at the first large group meeting. A second pretest over fractions is given during the first week of classes. Scores on these tests are posted by student number. Since the scores can assist the instructors in helping the students, students should discuss the significance of their scores with the instructors. In the light of a student's scores, an instructor may recommend a modification of the student's program.

Performance on the series of qualifying tests determines whether or not a student remains in the program and whether or not he receives a grade. Note the following.

1. To receive a grade of *C* or better, a student is expected to complete the entire program.
2. A minimum grade of *C* will be assured those students making satisfactory scores on all qualifying tests.
3. Grades of *B* or *A* will be assigned to students having a record of high-level performance in the course.
4. Students who have completed 60% but less than 100% of the program will be assigned "incomplete," or *I*. These students are expected to complete their program during the next session; failure to complete the work will result in a grade of *F*.
5. Students who do not complete 60% of the program will be requested to change to "audit," or *N*; failure to make this change will result in a grade of *F*. These students are expected to enroll in CY 150-151 for the next session so that they may complete their program; they will not be required to repeat work which they have completed.
6. Progress reports will be made according to the following:

A and *B*	Maintains work schedule with outstanding performance.
C	Meets 70% of work schedule.
I	Fails to meet 70% of work scheduled but completes at least 50%.
F	Fails to complete 50% of work schedule. (These students should change to "audit" or withdraw from the course.)

7. For each test, except the pretests, the student will be given a set of performance objectives stating what he is expected to be able to do on the test.
8. Before being assigned a qualifying test, the student must present evidence of his preparation for taking the test.
9. Qualifying tests over any given set of material may be taken repeatedly until a satisfactory score is made; however, there must be evidence of remedial work done between each attempt.

Attendance

Each student is expected to schedule six hours per week in the program facilities. These six hours include:

Lecture-demonstration	1.0 hour
Laboratory section	3.0 hours
Seminar	.5 hour
To be arranged	1.5 hours

Attendance and time spent are recorded on time cards. This information is periodically summarized by computer.

As a rule the student is expected to spend eight hours per week of study above the six hours scheduled. When space permits, the student is welcome to spend some of these hours in the program facilities.

AN EXPERIMENT IN AUTOMATED INSTRUCTION: COLLEGE CHEMISTRY I

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Sacramento City College, Sacramento, California

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and reprinted here with the permission of

The introductory chemistry course for professionals at Sacramento City College is unfortunately traumatic. A high drop-out rate (40% up) characterizes even the best presentations. An explanation frequently offered is that many qualified students, especially from minority groups, lack scholarship habits necessary for conventional chemistry instruction.

The Approach

Instructional technology has developed to the point where it is possible to offer automated, and yet highly individualized instruction to large classes. It is technologically possible, for instance, to present an entire course to each and every member of a class of one hundred students without the usual "lock step" requirement (all do the same lesson on a given day). Systems are available in which each student may proceed through lessons appropriate for him at a rate commensurate with his or her capabilities. Exams are frequent and may be retaken until an acceptable performance is achieved.

Are such systems necessary or even desirable at this college? Recently, I gave a Chemistry I examination that produced a few grades in the nineties, a class average of 55 and a low of 21. The standard deviation was quite large (= 17). This exam score distribution is typical of student performance in many community colleges. Often the grade distribution will show four or five distinct maxima instead of one. Obviously the concept of the "class" as a group of students that may be taught collectively is hardly applicable to such situations.

The Technology

Chemistry teaching, like any other presentation, breaks down into specific knowledges, skills, attitudes, understandings and appreciations. Each of these five areas of learning demands its own instructional approach and evaluative procedure.

Manual laboratory skills, for instance, are usually taught by the instructor demonstrating to the student the position of the hands, the movements, etc. Very often the student is unable to see the demonstration adequately because the point of visual emphasis is small compared to the visual field. Also, the time of the demonstration may not coincide with the learning priorities the student has established for himself. (The teacher sets up the demonstration and presents it--but half or more of the students turn it off because they are not quite ready.)

Why not incapsulate the presentation in a cartridged, sound film which the student can play when he is ready? This is possible through the use of the Fairchild Mark IV rear screen cartridge projectors. Fifteen such cartridges were developed locally. Most simply demonstrated proper technique for performing a specific lab experiment using the identical experiment and facilities the student would later confront.

Detailed knowledge and understanding are a different matter and more difficult to cope with. The procedure used included films and linear programmed instruction followed by weekly quizzes. Students who failed the quiz were recycled on the program and required to take the quiz again. If a hang-up in this formula developed, then the instructor would step in for a private lesson with the individual experiencing the difficulties.

Experimental Design

Two random sections of Chemistry 1A were designated for the experiment during the spring of 1970. Although no attempt was made to match the two groups for ability or achievement in Chemistry, ACT, math and natural science scores were available for about half the students in each section. These showed small but insignificant differences (see data page).

Students in the experimental section were given the list of assignments that constituted their course (see course outline at the end of this report). They were informed (by handouts) that no lectures were planned for the course. All subject matter would be presented by films, programmed instruction or as answers to specific questions directed to the instructor. The instructor was available for questions during the afternoon class periods.

A multiple choice, computer-graded examination was given about every 4th or 5th session. Any student who made a grade of 60% or below was permitted to retake the same exam as many times as necessary until a score of 70% or better was achieved.

The programmed instruction was specific sequences from *Numbers and Units for Science,*[1] and *Atomic Structure & Bonding.*[2] Additional short programs (handouts) were written by the author for (a) sequences unavailable in the two main programmed books or (b) available sequences judged to be inadequate.

The films were both 16 mm reel and regular and super 8 mm cartridges. Most of the 8 mm cartridges were sound cartridges using the Fairchild Mark IV rear screen sound projector.

The instructional procedure in the control section consisted of 3 hours per week of lecture and 6 hours per week of conventional handspanked laboratory in which the students emphasized the first five letters of Laboratory and the instructor emphasized the last seven. The behavioral goals for the two classes were identical. The control section was presented with the same material as the experimental section except that no media were used.

Data
Entering ACT Scores (Averages)

	Experimental Section	Control Section
Natural Science	25.5%	23.0%
Mathematics	21.3%	21.7%

Drop Out Rates

Experimental Section (30 enrolled)	Control Section (33 enrolled)
25%	45%

Average Exam Scores

Experimental Section	Control Section
65% = 7.2	63% = 8.8

Rate of Successful Completion (A's, B's, C's)

Experimental Section	Control Section
60%	53%

Scores on Laboratory Practicals (Chemical Unknowns)

Experimental Section	Control Section
56%	51%

Discussion

It is dangerous to base judgments of instructional efficacy on results involving only 63 students. Even so, several facts emerge from the data.

1. The data showing that student scores in the experimental section were not much better than in the control section may overshadow an important fact: they weren't any worse. One is tempted to conclude that formal lectures may largely be wasted effort, especially when the subject matter is of a terse, highly technical nature. This material can be presented more effectively with a repeatable printed visual format than with a one shot audio (lecture). Of course, there will always be problem areas in a subject and there will be problem students. But these situations should be dealt with on a one-to-one teacher–learner basis, time for which is made available through the automation of the more routine part of the presentation.
2. The experimental section retained 75% of the enrollees. The control section retained only 55%.
3. The experimental section generated a more homogeneous product (= 7.2) than the control section (= 8.8). This may seem a small matter, but quality control is an important factor generally ignored by many teachers and institutions. If the input is less variable, should not the output also be more consistent? Is not consistency of instructional output at each point in the curriculum something that is tacitly assumed by all planners of instruction? Is a "systems approach" totally irrelevant in higher education? Call it as you will, I tend to feel more comfortable about a class in which the standard deviation is not inordinately high.
4. In laboratory, for which the cartridged films were most specifically designed, grades in the experimental section were 10% higher than in the control section.

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1. Harris, Frank, *Numbers and Units for Science*
   Addison Wesley, Mass., 1963.
2. Dawson, Charles R. et al., *Atomic Structure & Bonding*
   Appleton Century Crofts, Chicago, 1962.

SPECIAL TOPICS–INSTRUMENTATION

MODULAR INSTRUMENTATION

A Symposium on Innovations in Chemistry Teaching

An Introduction to the Symposium

William T. Mooney
Chairman, Committee on Chemistry in the Two-Year Colleges

In recent years there has been increased attention given to the use of instrumental methods for obtaining information about chemical systems and to the development of instrumentation hardware for use in college chemistry programs. Unfortunately, the development of instructional materials of software suitable for use in contemporary college chemistry classes has not kept pace with the hardware or equipment developments. Lagging even further behind the software development has been the establishment of accessible and effective programs to inform chemistry faculty members about such instruments and their applications and to train the faculty in the instrument utilization. There also needs to be established an effective communications network for evaluating and disseminating information about the hardware, the software, and the use of these in instructional programs.

Two significant instrumental developments in recent years are the appearance of low cost, student-proof, reliable instruments and the development of modular instrumentation systems.

The Two-Year College Chemistry Conference has a role to play in bringing to the chemistry faculty of the two-year colleges information about and demonstrations utilizing new instructional equipment and materials suitable for use in college chemistry. The Conference also has a role in encouraging chemists in these colleges with ideas and interests in utilizing such equipment to develop materials suitable for use in the chemistry programs of the two-year colleges. To fulfill these roles symposia on Innovations in Chemistry Teaching are scheduled as a part of the Conference programs.

The Syposium on Modular Instrumentation includes presentations of instruments and their utilization in such a way that two-year college chemistry faculty should be informed and stimulated to go home and develop plans for the improvement of their instructional programs through the use of these or similar instruments. It also makes a contribution by presenting to the conference attendees both the potential contribution to instructional improvement and the problems associated with the introduction of any of the instruments or techniques presented at the Conference.

WHY CONSIDER THE USE OF INSTRUMENTS IN THE LOWER DIVISION OR TWO-YEAR COLLEGE?

Robert Pecsok
University of California, Los Angeles, California and Chemical Technology Curriculum Project

Presented as the Keynote Address at the Symposium on Modular and Low-Cost Instrumentation, 26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.

Let us begin this discussion of why we should consider using instruments in lower division chemistry courses by first examining the situation regarding instrumentation in the early 1940's. The most intricate equipment used at that time was the two-pan balance. The most valuable laboratory apparatus was a set of gold-plated weights. The equipment that was available in significant quantity consisted only of beakers, burets, flasks, funnels and, above all, the rubber policeman. To judge the viewpoints of some of my contemporaries, they must still have this view of analytical chemistry. They hated the subject when they were students and they still hate it as a course requiring tedious and uninteresting procedures.

The ability of chemistry departments to purchase instrumentation has certainly vastly improved in recent years. It has often been easier to order a $50,000 or $100,000 instrument than to get a typewriter. To a large degree the image of the chemistry department has depended upon the amount of money available to be spent on instrumentation. By itself this is not a good reason for using instruments in elementary classes. The important justification of the use of instrumentation in these classes is that it holds student interest while much more accurately reflecting what modern chemistry really is.

We should begin the practice as soon as possible of having students do things the way a chemist does them. Once a particular viewpoint has been accepted by a student, it becomes difficult to teach him that there are better ways of doing the same thing. It is much like learning to drive and then having to completely change driving habits. Many of the topics that we discuss in lectures in lower division chemistry courses can be discussed only becuase of instrumental measurements. We should do everything possible to make the laboratory experience relevant to what is presented in the lecture program.

We should note that in 1940 pH meters were just becoming widespread. There were perhaps a dozen polarographs throughout the country and there were no books about polarography written in English. The famous DU spectrophtometer was not yet in existence and only a few homemade IR spectrophtometers existed, none of them having gratings. There were no radioisotopes that could be used except for radium. Paper chromatography was still unknown; the nuclear magnetic resonance spectrometer was unknown; and there were only a very few mass spectrometers in physics laboratories.

All of these instruments are now accepted as requirements for conducting chemistry. The availability of these instruments and procedures has drastically changed the real and practical nature of analytical chemistry. It is no longer adequate just to determine composition; organic chemists want to know the molecular structure of compounds in great detail. In semiconductor work determination of traces of contaminants is much more important than determining the purity of the bulk elements present. It may be nice to know the purity is 99.9% or 99.99%, but what is really important is the parts per million and even parts per billion. Medical applications of analytical chemistry require that we determine the amounts of trace metals and where they are found. Mercury has been in fish for a long, long time; however, it was not considered to be a problem until analytical methods were developed that permitted determining the mercury content once it exceeded 0.5 parts per million. Archeology and art history have become completely different subjects with the sophisticated analytical techniques that we now have. For use in these fields, the technique must be nondestructive; afterall we can't very well titrate the Mona Lisa. We now have instrumentation which permits us to analyze moon samples even while they are on the moon and we have made a start on the analysis of the atmosphere of planets. It would seem possible that we could send an analytical chemist to the moon with a suitcase full of beakers, burets and standard reagents, but somehow it just doesn't seem right to titrate the moon. Modern industry could not exist without an arsenal of rapid, dependable, precise, automatic instrumental methods for process control. There are many situations that exist which simply do not permit the time to be used to make an extraction and filter a precipitate, requiring a minimum of two or three hours of digestion and drying time.

The reasons for including instrumentation in lower division chemistry courses should seem obvious. The question is how do we get the instruments into the classroom. The research quality instruments are much too expensive to buy and maintain for use in undergraduate laboratories. They require too much space and take too much time for students to learn how to operate them. They frequently remain "black boxes" and thus lose a major aspect of their instructional potential. However, there are some research quality instruments that can serve the dual purpose of instructional instruments as well as a research instrument.

In the last couple of years, low cost educational models have appeared in most instrumental areas with sufficient quality so that they can be practically used. Many of them are now rugged, dependable and accurate but are not necessarily sensitive or have the wide range versatility demanded for research instruments. Instrument companies have become interested in this particular market even though they may have been interested only in the most sophisticated high-priced units when money was much more plentiful. Many of the instruments are now available with visible access to the operational features of the instrument. This approach permits the students to see the plumbing and wiring that go together to make a workable instrument. Even in the area of mass spectrometry and NMR, the spectrophotometers are now available at moderately low costs and can be expected to see use in lower division chemistry courses in the near future.

The modular approach to instrumentation sounds good but it has many pitfalls. In general, modular instrumentation has not advanced or become as acceptable as many people thought it would. This approach seems satisfactory if students are being taught how to build instruments rather that how or why to use them. It appears that many teachers believe the do-it-yourself approach is best suited for individual projects where time is of less concern.

GAS CHROMATOGRAPHY AT RHODE ISLAND JUNIOR COLLEGE USING A CARLE GAS CHROMATOGRAPH INSTRUMENT

Harry Hajian
Rhode Island Junior College, Providence, Rhode Island

**Presented at the Symposium on Modular and Low-Cost Instrumentation,
26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.**

Instrumentation in the area of chemical analysis has become the rule rather than the exception. This proliferation of instrumentation demands that it be introduced very soon in a chemistry course. At Rhode Island Junior College instrumentation is introduced within the first three weeks of the freshman year to the chemical technology students. For the sake of educational expediency on the part of the instructor and a meaningful experience on the part of the student, the choice of instruments must be carefully investigated.

In the area of gas chromatography, a standard instrument may be so complicated that the opportunities for mistakes by the student in preparing the chromatographs for usage are increased and achieving meaningful results during a laboratory period are decreased. There are a number of gas chromatographs available that are fairly simple to operate yet produce readable and meaningful chromatograms.

In the development of the ChemTeC Project materials, the consensus of opinion was that an instrument similar to the Carle gas chromatograph instrument would best suit the course. The instrument is introduced by showing a film developed by the ChemTeC Project for this purpose. The film is 12 minutes long and is followed by the instructor's demonstration of the instrument.

After the students are introduced to the instrument, they get the feel of it by running samples of pure solvents which are used to measure retention times. These chromatograms are used later to identify components in commercial products such as cleaning fluids, after-shaving lotions, fingernail polish removers and other such products.

At this point the students should be able to follow the courses of a fairly sophisticated chemical reaction using the Carle gas chromatograph. The reaction chosen, an ester exchange, illustrates that all chemical reactions do not necessarily go to completion.

The laboratory group can be divided into two sections allowing the forward and reverse reaction to be investigated simultaneously. After standard chromatograms of ethyl acetate, methyl acetate, methyl and ethyl alcohol, (the components of the system) are obtained, Group I may prepare reaction (1) ETAC & MEOH → products while Group II may prepare the reaction (2) MEAC & ETOH → products.

After chromatograms of the reactants in Reactions (1) and (2) are obtained, a chromatogram of the reaction mixture is run. Using a water bath stabilized at 45°C, the reaction is allowed to proceed. After fifteen minute intervals, four $1.0\ \mu l$ samples from the reaction flask are injected into the gas chromatograph. Chromatograms of the reaction are run at the end of the laboratory period. The reaction flask is then stored tightly stoppered until the next laboratory period at which time a final chromatogram is obtained.

Some interesting conclusions can be drawn from the exercise:

1. Products are formed on heating the reaction mixture and from this an equation can be written.
2. The products of Reaction (1) seem to be the same as the reactants of Reaction (2) and vice versa. This is seen by comparing the retention times of all peaks in both reactions with each other and with the standard samples.
3. The chromatograms from the end of the experiment and those run on the same mixture during the following laboratory period show that for both mixtures the reactions have apparently stopped. That is, within experimental error relative peak heights have not changed.
4. It is apparent that Reaction 2 proceeded at a slower rate than Reaction 1.

GAS CHROMATOGRAPHY AT SIERRA COLLEGE USING THE VARIAN AEROGRAPH 90–P3 GAS CHROMATOGRAPH

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**Presented at the Sympsoium on Modular and Low Cost Instrumentation,
26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.**

In our program at Sierra College, the student is introduced to gas chromatography by means of an experiment that is one part of a continuing series. First, the student performs standard distillation experiments using a binary mixture of unknown composition, trving first a simple distillation technique, then fractional distillation. The procedure followed is that in *Modern Experimental Organic Chemistry*, by Roberts, Gilbert, Rodewald, and Wingrove. However, instead of using the benzene-toluene mixture suggested in the manual, we have them use an unknown mixture. Very suitable substances to be used for unknowns are the isomeric butyl alcohols. We use a mixture of 2-butanol (b.p. 99.5°C) and l-butanol (b.p. 117.5°C). After completing the fractional distillation, the students save their recovered fractions for future analysis by gas chromatography.

Following the distillation experiments we go into a study of methods of separation based upon phase distribution. We start first with a simple extraction experiment, then go into paper chromatography, then gas chromatography, showing in each case how the new technique corresponds to those previously studied.

We first consider the general physical system that is the gas chromatograph. We develop a flow diagram showing the essential parts of the instrument by tracing the carrier gas from the cylinder through all parts of the instrument until it finally vents into the air. This serves to acquaint the student with the sequence involved. We then turn our attention to a detailed consideration of two parts of the gas chromatograph: the detector and the column.

In considering how the detector works, we have found that the students can rapidly gain a feel for how a wheatstone bridge circuit works, even if they have had little electrical theory.

Having previously studied paper chromatography, the functions of the carrier gas and of the components of the column rapidly become clear. They see the carrier gas as the mobile phase, corresponding to the eluting solvent in paper chromatography; the solid support corresponds to the cellulose fibers of the paper; and the stationary liquid phase coating the solid particles in the column corresponds to the adsorbed water on the cellulose fibers. At all times we strive for a "molecular awareness" so that the students can visualize in their "mind's eye" the progress of their samples through the chromatograph.

Following the preliminary discussion the students inject their own samples into the system. This must be done under careful instructor supervision because of the extreme ease with which the syringe can be damaged. We use a 10 μl syringe equipped with a guide mechanism because of the very small samples used. The average sample sizes run from 0.5 to 1.5 μl.

The real satisfaction from this experiment comes when the students see their chromatograms coming off the recorder. It is difficult to convince a student that his fractional distillation is not 100% efficient, but when he sees two peaks instead of just one on the chromatogram, he is forced to accept the fact that the distillation is not perfect.

Sometimes (indeed, rather frequently) an extra peak is observed that the student can't account for. It invariably appears between the air peak and the first component peak and can readily be identified as acetone. A very valuable point can be made here regarding the common practice of using acetone to aid in drying glassware. The purity of their samples is then calculated in percent, utilizing the integrator trace.

Following this the students then turn their attention to phase three of this continuing experiment by running the same samples on the infrared spectrophotometer. This completes the sequence by enabling the students to identify the components of the mixture they started with back in the distillation experiment.

The remainder of the laboratory course includes several synthesis experiments. Each liquid prep is analyzed by the student on the gas chromatograph and the chromatogram becomes a part of his lab record.

The Varian 90-P3 is a gas chromatograph which is well adapted to the student laboratory in lower division instruction. Fundamentally it is a rugged, dependable instrument that is easy to use. It is a single column instrument using a thermal conductivity detector. This provides for a very rugged, sensitive and amazingly stable unit that is well suited to routine student use. The chromatogram is recorded on a Leeds and Northrop Speedomax W recorder, equipped with a Disc Integrator.

Students quickly learn the necessary techniques in the gas chromatograph's operation and soon take its use for granted. Gas chromatography has become an integral part of our laboratory program and complements the other analytical techniques available to the student.

GAS CHROMATOGRAPHY IN INSTRUMENTAL ANALYSIS AT QUEENS COLLEGE USING A GOW-MAC INSTRUMENT

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Presented at the Symposium on Modular and Low-Cost Instrumentation
25th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971

At Queens College, Instrumental Analysis is a one-semester course normally taken after Quantitative Analysis and simultaneously with second semester physical chemistry. Ten laboratory experiments and a special project of the student's choosing and development are performed, covering separations, electroanalytical chemistry and analytical spectrophotometry. Two lectures and one six-hour lab period are scheduled per week. Usually because of equipment limitations, students work in pairs. Molecular characterization by IR, NMR, etc., is treated in Qualitative Organic Analysis and consequently is not covered in Instrumental Analysis.

Emphasis is placed on gaining familiarity with using instruments rather than on high quantitative accuracy. Nonetheless, the quantitative results tend to be rather good considering the difficulty even the most experienced have in successfully executing a procedure the first time through. Sophisticated instrumentation is really unnecessary and even undesirable at this level. In any case, we are in no position to tie up expensive "research" equipment for use only once a week.

The gas chromatography experiments described here have worked out very well, being trouble-free and easily comprehended by students. We have had very good experience with the GOW-MAC gas chromatograph. Having long been satisfied with GOW-MAC thermal conductivity detectors in homemade and commercial GC's, I was delighted to see their Model 69-100 Educational Gas Chromatograph introduced. Indeed, I managed to get serial number 1. They have maintained their standards and we have since purchased two more units and intend to obtain two more next year.

Other GOW-MAC GC's are being used at Queens College for undergraduate and graduate research. While CUNY is not yet able to supply one GC per student, the availability of low cost instrumentation allows us to place at least one GC in each lab.

Description of the Instrument

The GOW-MAC Model 69-100 is a convection-heated, isothermal, dual column, two-filament, thermal conductivity instrument. A diagram is shown in Figure 1. It comes in two sections; one section contains the electronics and controls, and the other, the upper part, is the gas chromatograph itself. When the two sections are separated for use, about two square feet of bench top are occupied.

Two different columns may be installed. More than 16 feet of ¼-inch tubing can be placed in the oven. Columns of different polarities, for example, can thus be used successively on the same mixture to demonstrate the effect of stationary phase polarity on selectivity. The oven is heated by convection from the block containing the two injection ports and detectors. Column temperatures to 250° C and injector-detector temperatures to 280° C can be reached. With the cover off, the instrument can be operated at ambient conditions.

The thermal conductivity detectors use the new gold-sheathed tungsten filaments which are more resistant (though not absolutely immune) to air oxidation than WX filaments and thus last longer. The power supply is all solid state. Sensitivity is entirely adequate for all our purposes.

Flow rates in the two columns can be individually controlled by means of Nupro valves. Injection is by syringe. We have had considerable loss of syringes through bending of the plunger and, therefore, use $12 Glenco syringes rather than $18 Hamiltons.

A one, five or ten mv recorder may be used. Larger samples are,of course,required with less sensitive recorders. We have used the inexpensive Heath recorder (10 mv), the 1 mv Sargent, and the 1 mv Varian recorder (which has a pen that works!),and all of them have their problems.

Components and operation of the GOW-MAC Gas Chromatograph are made clear simply by removing the cover. Like Fords built before 1957, it's all there to see.

The three experiments described here illustrate general principles of GC, quantitative analysis by GC and application of GC to a chemical problem. All use "real" samples (without making too big a thing about it) as opposed to completely synthetic mixtures. Normally, two of the three experiments would be done per semester.

Experiment 1: Introduction to Gas Chromatography

Some fundamental chromatographic variables are the subject of this experiment. The separation of multicomponent mixtures of very similar compounds is also clearly demonstrated. The analysis is one of considerable importance to the petroleum industry. The use of four blends as samples allows retention times to be measured unambiguously. Other combinations are possible and higher homologs can also be included at this temperature.

In practice, nice,straight lines are obtained for the plots of log V vs carbon number, boiling point and 1/T. With care, a typical van Deemter plot can be drawn from the hexane data. The importance of correcting for the carrier gas compressibility is also readily seen.

The experiment can be extended or expanded (or contracted, for that matter) to include quantitative analysis of unknown blends, lighter fluid samples (which have C_9's and higher boiling materials in them), petroleum ether, etc. Slight modification allows use of the experiment in physical chemistry lab: if the precise weight of squalene on the column is known, the specific retention volumes of all constituents can be calculated and from these the infinite dilution activity coefficients. It is the nonideality of the squalene-hydrocarbon solutions that renders the GC separation possible. Other thermodynamic quantities can be derived from the termperature dependence of the activity coefficients.

(Details of the experiment can be obtained by writing to the Editor of these *Proceedings*.)

Experiment 2: Analysis of Xylenes by GC and by IR

Quantitative analysis of the same sample by two different techniques simultaneously offers immediate comparison in terms of time, technique required, ease of sample handling, calibrations required, data interpretation, etc. The experiment on IR analysis in Ewing's *Instrumental Methods of Chemical Analysis* has been used by us previously by itself; the GC part was introduced this semester. The GC results have been far better than the IR results.

It is possible to demonstrate trapping and peak identification by a simple extension of this experiment. By using larger (50 μl) samples containing these compounds and possibly some higher aromatic homologs, peaks can be trapped at the exit port of the chromatograph in a small, bent, glass U-tube placed in a dry ice-acetone bath. The GOW-MAC can be placed on top of the recorder or on a small box. The glass tubes can be rinsed out in a small volume of cyclohexane and identified by IR or another spectroscopic technique. Repetitive injections may be necessary to obtain sufficient sample for IR.

Experiment 3: Kinetics of Methanolysis.

This experiment requires some background in chemical kinetics but serves as a good example of the use of GC for obtaining kinetic information. This experiment shows the separation of a reaction mixture quenched after 40 min.; the peaks are methanol (solvent), ethanol, and the three acetals. Note that the GOW-MAC GC will hold both a 10 ft. and a 6 ft. column at the same time; if necessary, one could perform both experiments on the same day without changing a column.

Typical student results for peak area vs. time are shown in Figure 2 and the log plot in Figure 3. The results obtained at Queens College agree well with those reported by Johnson.

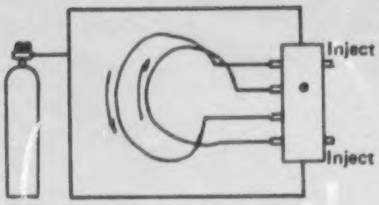


Figure 1: Gas Flow System

Figure 2: Student Data for Peak Area vs Time

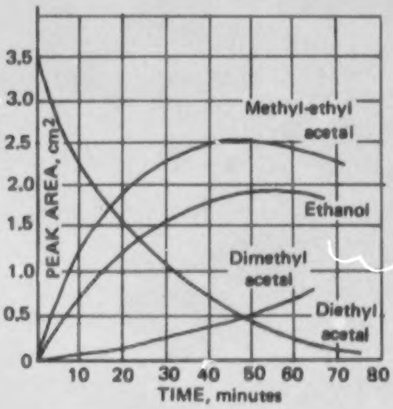
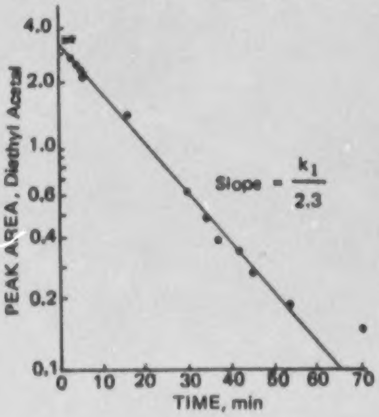


Figure 3: A Log Plot of Figure 2 for Diethyl Acetal



INFRA-RED SPECTROSCOPY AT PHOENIX COLLEGE USING THE BECKMAN MICROSPEC INSTRUMENT

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Presented at the Symposium on Modular and Low-Cost Instrumentation,
26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.

The Beckman Microspec instrument has many applications. With the Wilks Minipress you can run IR spectra on any solid sample if a simple procedure is followed. Be sure that you: 1) use dry Harshaw grade KBr, 2) keep samples as dry as possible and 3) grind the sample well. To keep the instrument in good operation, the thermocouple must be kept dry. This can be accomplished by installing a light which will keep the temperature of the instrument high enough to dry the thermocouple or by buying the heating unit furnished by the company. The Wilks Mini-cell makes the instrument very usable in inexperienced (student) hands.

The Microspec produces spectra of acceptable quality. In a comparison of the spectrum of anthranilic acid from a Perkin-Elmer instrument with the spectrum given by the Microspec, the same peaks appear. However, the Microspec does not give as good resolution as the more expensive instrument. Similar comparisons made with ethanol on the two instruments give similar results. A comparison of the Microspec's spectra of two samples of benzyl alcohol (one sample prepared by a student in an organic class, the second sample taken from the stockroom) shows the presence of benzaldehyde in the stockroom sample.

The Microspec has drawbacks in addition to poorer peak resolution than more expensive instruments. As with all IR spectrophotometers, it is all too easy to graphically illustrate to students that water is an impurity and must be kept away from windows. The salt windows are difficult to keep transparent, and grinding the windows is a tedious process.

Among advantages, the Microspec provides a usable, cheap approach to teaching students about infrared spectroscopy. Many good spectra are available for comparison. (Spectra of common liquids can be obtained from Rod O'Conner at the University of Arizona.) Such spectra help to give the student confidence. When a student has confidence in his instrument, he can then realize how it can be used as an analytical tool to find the purity of samples.

INFRARED SPECTROPHOTOMETRY AT SANTA ROSA JUNIOR COLLEGE USING A PERKIN-ELMER MODEL 700 IR INSTRUMENT

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Presented at the Symposium on Modular and Low-Cost Instrumentation,
26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.

The Santa Rosa Junior College chemistry department purchased a Perkin-Elmer Model 700 infrared spectrophotometer. In addition to the initial purchase of the instrument itself, we also purchased: 1) two demountable holders and six NaCl prisms, 2) two AgCl windows, 3) two fixed-pathlength NaCl cells, 4) one gas cell, 5) one Perkin-Elmer KBr pellet die, 6) one pellet holder, 7) additional recorder pens and chart paper. During the past three years of operation, the following additional items have also been purchased: 1) one large and two small desiccators, 2) one vacuum pump, 3) one pellet die press, 4) one small agate mortar and pestle, 5) one modified Wiggle-Bug, 6) one set of window refinishing materials (home-grown), 7) one hot air blower.

Maintenance of the instrument and the accessory equipment has not been a very large problem. The Model 700 has required no maintenance other than adjustment of the gain and slit by our staff. The instrument is always covered when not in operation and the power cord is unplugged to prevent the instrument's being accidentally energized. The NaCl windows occasionally require refinishing. This has been minimized by insuring that all samples are dry and that all windows are washed with benzene dried over sodium immediately after they are used. The cells are then stored in a desiccator. Fixed cells are rinsed with dry benzene and then aspirated through a calcium chloride tube immediately after use.

During the two-year program we expect the student to become familiar with this instrument and begin using it routinely. In Chemistry 1A-1B we use this instrument for: 1) infrared absorption correlations with bonding, utilizing student-synthesized sulfur oxyanions and 2) the verification and effect of complexation upon chelate stretching vibrations. (Our present laboratory text is *Experimental General Chemistry* by Lippincott, Meek and Verhoek.) In Chemistry 2A-2B we expect the student to use the instrument for identification of functional groups by verifications in the fingerprint region. The present laboratory text is *The Elements of Chemistry in the Laboratory* by Lawrence P. Eblin and *Introduction to Laboratory Chemistry: Organic and Biochemistry* by Williams, Richardson, DeBey, Kelley and Lien. In Chemistry 8 we use this instrument for verification and identification of synthesized products in six experiments with which we supplement the basic laboratory manual. (The present laboratory text is *Organic Experiments* by Linstromberg and Baumgarten.) For Chemistry 12A-12B we use the instrument extensively for identification and verification of molecular structure. The instrument is used in conjunction with refractometry, UV-visible spectrophotometry, gas chromatorgraphy and melting and boiling point determinations using the Mettler FP-1. (The present laboratory text is *Organic Experiments* by Linstromberg and Baumgarten with supplements and *Experimental Organic Chemistry* by Marjorie C. Caserio.)

By rotating the experiments assigned to be done on the instrument, one can adequately get along with a minimum of accessories. We have found the following list to be adequate: 1) NaCl demountable cells with appropriate gaskets for fixed pathlengths, 2) two mini-dies with torque wrench, 3) one vacuum pump, 4) a few desiccators, 5) a few agate mortars and pestles, 6) some NaCl windows, 7) a refinishing kit for the windows.

A MODEL FOR TEACHING SPECTROSCOPY

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Presented at the Symposium on Innovations in The Teaching of Chemistry,
24th Two-Year College Chemistry Conference, New Orleans, December 4, 1970.

Spectroscopy represents an extremely important topic in chemistry instruction, even for elementary introductory courses, for a variety of reasons. Spectroscopic techniques are valuable tools in research and analysis for the identification of elements and compounds and for the elucidation of their structure. They are basic methods for quantitative analysis as well as in such diversified areas as pure research, industrial control laboratories, medical clinical laboratories, waste and pollution control monitoring, drug analysis, and so on. Spectroscopy has proven also to be a fundamental route to knowledge of molecular structure and properties bearing on chemical and physical behavior.

Although certain spectroscopic topics are mentioned and illustrated frequently in elementary textbooks, there are a number of problems associated with communicating these important concepts effectively. As generally presented topics dealing with spectroscopy are presented in such a piecemeal fashion, most of the students do not even sense the underlying common features or appreciate their fundamental nature. By and large, students in elementary courses do not understand

(1) what a spectrum is.
(2) what is involved experimentally in obtaining spectra.
(3) the quantities used to describe spectral features and spectral information (such as frequency, wavelength, energy, intensity, etc.)

In addition, students lack practical laboratory experience with these concepts.

Although few, if any, textbooks present spectroscopic concepts in a unified way, this deficiency can be remedied easily in the classroom and in the laboratory. It is important to maximize understanding of basic concepts by discussing them in a general, unified way and to be sure that fundamental ideas have been adequately illustrated. The following steps illustrate this theme.

1. *The general concept of a SPECTRUM should be clarified.* Any spectrum is essentially an ordered display of the components of some system. A simple example is the performance of students in a class as evidenced by their grades on an examination. If the grades scored are arranged systematically, starting with the highest and proceeding on through the lowest, then one has presented a spectrum of the grades scored. If, in addition, the number of students scoring each grade is also displayed graphically, one has a spectrum containing quantitative information as well. This is analogous to the spectrum of visible light in which the various kinds of light in a beam of light are sorted apart and arranged systematically in terms of their wavelength or frequency (which also correspond in visible light to a physiological perception of colors). If we plot also the intensity of the light of each wavelength or frequency, we have all the ingredients of a quantitative spectrum as usually presented graphically in a textbook. All spectra are similar whether they are infrared absorption spectra in which the radiation passing through a sample is plotted as intensity vs frequency, or mass spectra in which the sorting parameter is the mass/charge ratio of the ions formed in the spectrometer from a molecule and the spectrum is a plot of the number of ions of each type vs the mass/charge ratio of the ions formed in the spectrometer from a molecule.

These concepts can be illustrated easily in the classroom via demonstrations and films. A slit in the slide carriage of a 35 mm or lantern slide projector and an inexpensive diffraction grating outside the projector lens provide large, clear spectra with which properties of diffraction, color, absorption and similar effects can be shown.

2. *The functioning of SPECTROMETERS (devices used to obtain and measure spectra) should be discussed in general terms.* Despite seemingly different operating components and arrangements of these components, all spectroscopic techniques–using the idea of a spectrum as a basis–can be put into a common mold. For example, all spectrometers begin with a SOURCE of radiation or of particles such as ions or radioactive emissions. In some cases the material to be studied produces these, in which case we have an emission technique. In other methods radiation or particles are produced by a lamp, a discharge or some other means and this is then passed through the sample of material to be studied. This, then, is absorption spectroscopy. The means used to provide the radiation or particles depends on whether one is dealing with visible radiation, infrared radiation, radiofrequency radiation, molecular ions, etc.

The radiation or particles are next separated in an orderly way in any spectroscopic technique. Such a device might be termed the ANALYZER. In most forms of spectroscopy involving electromagnetic radiation, a prism or diffraction grating is used for this purpose. In a mass spectrometer the molecular ions are separated by means of electric and/or magnetic fields. Similarly, mechanisms can be identified for any spectroscopic method that performs this separation function.

Next, the radiation or particles coming from the ANALYZER are counted by means of a DETECTOR. Again different radiation may require different devices– a photographic plate, the eye itself, photoelectric cells of various kinds, etc. Finally, the response of this detector must be shown to the experimenter in some kind of DISPLAY. Typically this might be a needle on a meter or in some permanently recorded form. As the ANALYZER progressively selects various components of the original radiation, the DISPLAY shows the intensity of the radiation for each component (similarly for particles). This, then, is a SPECTRUM.

Again, these ideas can be illustrated with actual instruments and with simple demonstrations as well as with films.

3. *The properties of radiation and of particles and the parameters used to describe them must be understood.* A student can hardly be expected to understand what a spectrum is all about unless he understands the terms used to describe the components that are displayed. All too often elementary chemistry texts assume that the beginning student already is an expert in physics.

Particles involved in spectroscopy generally are described by parameters such as mass, charge, velocity, momentum and energy. Some of these may well require review. If magnetic resonance is to be discussed, the idea of spin angular momentum also is required. Radiation is described by parameters such as wavelenth and frequency. These are seldom understood by the student. Fortunately, it is simple to illustrate these concepts in some detail via demonstrations and films using water waves as a starting point. After all, interference and diffraction patterns are the basic way of determining the wavelength of light and therefore provide a natural bridge to wave phenomena, such as water waves, that the student actually can see. Once these ideas are clarified and the numerical values associated with visible light are examined, the expectation that radiation of other wavelengths and frequencies might exist, even though invisible to the eye, is easy. The energy content of radiation and the photon concept also can be illustrated in simple ways.

4. *It is important that the student have contact with these concepts directly in the laboratory.* Simple slits, diffraction gratings and color filters are inexpensive and provide a means for students to examine properties of light and the effects of a grating (ANALYZER) on light. Although complex spectrophotometers are expensive, simple filter photometers and simple spectrophotometers are well within the range of most budgets. These instruments provide an opportunity to examine such things as the intensity of light from a source as a function of its frequency or wavelength, the effect of having an absorbing medium (a color filter or a colored solution) in the beam (quantitatively as well as qualitatively), and various ways of plotting intensity vs. wavelength information. In addition, such simple instruments provide direct observation of the operating components uncluttered by confusing refinements, and actual meaningful analyses can be performed similar to those that would be carried out in a medical, industrial or government laboratory.

Fortunately, not only are many of these concepts amenable to a more logical treatment than found in texts and to simple and effective demonstration in the classroom, a great deal can be done via self-instructional media and in the laboratory. Many of the early physics projects such as PSSC and IPS produced useful films and film loops on color, diffraction, wave motion, etc. More recently, films in this area aimed at chemistry instruction, such as the Spectroscopy Series produced by Holt, Rinehart and Winston, have appeared and provide a means for students to study these concepts on his own as long and as frequently as necessary. Visual illustration and actual contact with the techniques are the only way in which some of the abstract concepts can form effectively in the beginning student's experience.

SCIENCE TEACHING IN MODERN SOCIETY

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Presented at the Symposium on the Interrelationship of Chemistry and our Society, 26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.

This is a discussion of the scientific and technological problems society currently faces such as air pollution, water pollution, food additives, radioactive contamination, drugs, pesticides and waste disposal. I'd like to propose a definitive solution to each one.

I choose three "age" cliches to suit my purposes. First, we are living in the Age of Communication. With several communications satellites in orbit over our heads at this very moment we needn't belabor that point. Second, these times have also been characterized as an Age of Technology. Behind the technology is science, so we'll call it the Age of Science. And finally as the song tells us, we are living in the Age of Aquarius, by which is meant the Age of Youth.

In a real sense we, the teachers of the scientists and technologists, are right in the middle of all the action in today's society. In the Age of Communication, Science and Youth, we are in the business of communicating science to youth. In the vernacular, we're right where it[s at. I'm going to puncture the bubble of self-importance by asserting that in at least one important respect we've been botching the job.

Just as it is fashionable to talk about society as an Age of *Something*, it is also quite fashionable these days to talk about gaps. As a matter of fact there is a gap associated with each of the Age characterizations I've chosen for present-day society. We who communicate science to youth are faced with having to bridge all three of these gaps. Associated with communication is the Communication Gap. This gap has always existed whenever two people have gotten together in the same room and the classroom is by no means an exception. Second is the Generation Gap. It too has always been present in the classroom: the person standing up in front has almost always been over thirty while the people in the seats have been under thirty.

Trying to close the Communication Gap and the Generation Gap is simply the business of teaching. There is a third gap associated with the Age of Science. This one has been with us for over thirty years, but was first formally documented about twelve years ago by C. P. Snow. It is the Two-culture Gap: the gulf, the mutual lack of understanding which exists between scientists and what might be called the rest of society. The point I want to make is that we who teach science seem not to realize that we should be working to bridge that gap as well as the others.

Consider some recent trends which might be attributed in part to the widening of this Two-culture Gap. The government has been drastically cutting its support of scientific investigation; industry is trimming away fat; significant numbers of Ph.D. chemists and physicists are unemployed; young people are not going into scientific careers? and there is a feeling on the part of many your people that technology has polluted our society and is "inhuman."

Today then, the two culture confrontation is no longer an academically interesting impasse as it was when Snow first wrote about it. It has become Them against Us. And we're losing.

Why am I rubbing salt in our wounds by pointing out that what we teach is no longer considered to be as important as it has been? I do so because I feel that it is partly our own fault. I do so because I feel that we have an opportunity and even an obligation to nibble away at some of the misunderstandings upon which this gap is based. We have an obligation to try to counteract, or at least to slow down, our society's disenchantment with science–for its own ultimate good.

Whenever there is danger of misunderstanding, there is a teaching job to be done. Yet as teachers we have permitted these larger misunderstandings to persist while thinking only about how best to convey an understanding of the chemical bond. Teaching chemistry as well as we can is no longer enough. If we continue to spend all our time debating the relative pedagogical subtleties of one approach versus another, we are going to wake up to find that there is nobody to teach—unless, in addition to teaching the chemistry, we start eaching also *about* chemistry, *about* science and *about* scientists and what parts they play in society. Unless we start teaching some music along with the words, the misunderstanding will continue to flourish, the gap will become a trench, science will fall much too low in priority and our society will have made a costly mistake.

What are these misunderstandings and what can college chemistry teachers do about them? First, let us realize that most of the people in our chemistry classrooms are not going to become professional scientists. They are the future engineers, physicians, lawyers and thousand of other unclassifiable non-professionals who will not be earning their livings by science. They are the "other culture." They are the very people who, by their own actions as future leaders or at least via the representatives they will elect, can either accelerate the ferment of disenchantment with science or temper it with an understanding of the true nature of the scientist and what he does in and for society.

This, then, is the first of the two jobs we now have to do besides teaching chemistry: we must shatter the distorted stereotypes of science and scientists which have been fed to and swallowed by a shockingly large fraction of our citizenry. You know the garbage we were all brought up on: the scientist is a sort of god in a white coat, devoting his life to the selfless quest for truth, forsaking all worldly temptations, and so on. The young person hearing or reading these things is supposed to think, "My, how wonderful!", but he really thinks, "My, what a nut!" Or, as one of my students wrote in a revealingly unsuccessful attempt at understatement, "The scientist is different from your run-of-the-mill *homo sapien*."

Even some of us run-of-the-mill *homo sapiens* who became scientists because we tought "My, how wonderful!" instead of "My, what a nut!" discover upon growing up that we don't live up to the stereotype, and we secretly feel inadequate.

If people are led to believe that scientists are alien, unfeeling being with impenetrable motivations and superhuman intellectual abilities, they are just being challenged to watch for a chink in the armor. At the first sign of human fallibility, they pounce upon it much too hard. The result is suspicion of scientists, mistrust of science, and overkill of scientific research budgets. If people are led to believe through the wrong kinds of science courses that science is some kind of magical priesthood wrapped up in an unintelligible little world of its own, they'll abandon their intelligence and their citizenship whenever a technical issue of social importance arises. They will decide they are incapable of participating in its solution, and society again loses one of its important resources.

Paradoxically then, we can do both science and society a great service by using our classrooms to puncture the awe of science. Yank out the pedestal. Shatter the stereotype. Show our students both "good science" and "bad science" so they'll be able to recognize the good. Admit that there are some scientists with pet theories and inflated egos. Show scientists competing, disagreeing, making an honest and shameless mistake. Show how to evaluate the conflicting pronouncements of "experts." Show scientists being hired and fired, raising families, skiing, skin-diving and being liberal and conservative. Our students and other citizens must come to appreciate the importance of science *in spite of* its fallibility. Only by flaunting the fallibility of science as a badge of humanity can we expect our society's investment in science to come to rest at a level which is based upon an unemotional, realistic evaluation of science's importance; this will be lower than the undeservedly high level of the past 25 years, but certainly above the punitive level which befits a fallen angel.

I said earlier that we must teach these things *in addition to* teaching chemistry. Teaching *about* science without teaching the science itself is a worthless gesture. But the second new job we chemistry teachers have to tackle is to change the flavor of the chemistry we do teach. Since time is short I won't belabor the issue of relevance, which already has many other apostles. But it should be clear that the people in our classrooms today are those who will be expected to form opinions on such things as air pollution, Alaskan pipelines, oil spills, the disposal of nerve gases, and on the dangers of enzymes, radioactivity, phosphates, mercury, marijuana, the Pill and mind-modifying drugs. Should we spend all our time teaching them about molecular orbitals, or should we be giving them the applicable yet solid chemistry behind present and future technological issues?

Finally, what specific, positive actions can we take?

1. *Teach separate and distinct courses for those who are preparing themselves to join the two different cultures.* Current practice appears to be either to offer the same first-year chemistry course to everyone or to prepare a 12-molar course for the chemistry majors and to dilute it to 0.1 molar for the nonmajors. But watered-down major chemistry isn't what's needed by the "other culture." What is needed is a course which combines *applicable* chemistry with realistic material *about* chemistry. Both of these must be present in the same course which, for lack of a better name, we might call "Chemistry and Society."

As such solid courses replace the 0.1 molar nonmajor courses, why not open them up also to the majors? Students major in chemistry for many reasons other than to become professional chemists. Most of them, actually, are going into engineering or medicine which, in our context, belong to the "other culture." And why deny even the budding professional chemist an honest and realistic look at his intended profession?

2. *Assign readings from books and periodicals on "science and society" besides assigning chapters from the chemistry text in these courses.* A book report in a chemistry course, for example, is not as far-fetched in these times as it may seem.
3. *Invite real, live scientists to come and tell the class what they think they're doing in the world.*
4. *Discuss current news developments which have chemical overtones.*
5. *Analyze pseudoscientific arguments in advertising.*
6. Teach *applicable* chemistry.

Note that in this last item I avoid the word "relevant", which connotes ecessive immediacy. Applicable chemistry is not this-afternoon's-headline chemistry. Nor is it watered-down chemistry or pseudo-sociological hot air. It is the good, solid chemistry which is needed by every thinking citizen in today's and tomaorrow's societies to help him make decisions.

And if we don't deeply believe that chemistry *can* be applicable and *is* needed, we should take Harry Truman's famous advice and "get out of the kitchen."

CHEMISTRY: ITS EFFECTS ON OUR SOCIETY

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Presented at the Symposium on the Interrelationship of Chemistry and our Society,
25th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.

"It is an extraordinary era in which we live . . . remarkable for scientific research into the heavens, the earth; and perhaps more remarkable still is the applications of this scientific research to the pursuit of life . . . The progress of the age has almost outstripped human belief."

These words were spoken by Daniel Webster in 1847, 124 years ago, but they remarkably describe today's world. The applications of chemical research have improved the quality of life to such a high degree that we are living in what can be called a golden age—never before has man been able to devote so many leisure hours to the pursuit of culture, understanding, knowledge and pleasure. All of this is brought to you by the courtesy of chemistry. The beneficial effects of modern chemical developments are everywhere evident—we never had it so good. Chemistry is the chief source of all that is good in this world; better things for better living though chemistry. These statements reflect only one side of the picture; however, they are typical of only one segment of our society—the optimists.

Let me present another quotation.

"And I brought you into a plentiful country, to eat its fruit, and its goodness, but when ye entered ye defiled my land, and made my heritage an abomination." This quotation from Jeremiah 2:7 expresses very well the opinions of another large group of people concerning the effects of chemistry on our society. They view society as a group of doomed people, living on a polluted globe, breathing suffocating and obnoxious gases, wallowing in man-made filth—ugliness everywhere. Again, all of this is brought to you by the courtesy of chemistry. These are the opinions of the pessimists.

Which of these groups has the true faith? Are our decendants going to enjoy the benefits chemistry has wrought for society or will they be doomed—where lies the truth? What effect has chemistry really had on our society? Has it all be for the good or the bad? In my opinion the truth lies somewhere in between.

I would like to consider several chemical compounds and comment on the effects these compounds have had on our society, both the good and the bad, mention a few things that are being done and then draw a few conclusions.

Some of the bad guys are DDT, Dieldrin and 2,4-D. They represent a group of approximately 300 compounds known as pesticides. The term "pesticides" is a generic term covering fungicides, herbicides, insecticides, fumigants and rodenticicides. They are being produced in the United States at the rate of over a billion pounds per year. The biosphere now contains several million tons. They have produced quite an effect on our society. They can be credited with the saving of millions of human lives but they are also responsible for the pollution of much of our environment.

Historically the use of pesticides is not new. Consider the herbicides as an example. Herbicides were invented many years ago, probably by a female–a female of the species *odontotermes redemanni*, a termite. These social insects cultivate fungus gardens in their nests where the growth is limited to one species, *xylaria nigripes*. If one removes the termites from the fungus garden, other species of fungus soon make their appearance. The *xylaria* fungus is not itself responsible for the selective growth. The termites use a herbicide. The exudate from the anus of the queen termite contains caprylic acid; this is incorporated into the garden when worker termites cement the soil after licking the queen. Selective weed killers were used thousands of years before man ever got the idea, and there was no pollution of the environment.

The impact which pesticides have had on society, however, occurred following the discovery and massive use of DDT after World War II. Thanks to DDT it is estimated that one billion people have been freed of the insect-spread disease malaria.

James Wright, the Chief of Vector Biology for the World Health Organization, states that a major disaster would result from any action limiting the use of DDT for the control of malaria in developing countries (15 percent of the total production). He points out that the safety record for man has been outstanding; millions of lives have been saved and no toxic effects have been reported in the past 20 years among 200,000 spraymen employed in malaria campaigns nor among the 600,000 to one million people who live in repeatedly sprayed houses. The only known cases of DDT poisoning are those where people accidentally ate the stuff.

Now the bad side of the picture. DDT and related chlorinated compounds are ciocides. They are toxic to crabs, shrimp, fish, birds and mammals–in fact to all organisms which have a nervous system. Its immediate effect on organisms is to trigger spontaneous firing of nerve axons which results in acute convulsions and death. At sub-lethal dosages it leads to hyperactivity, nervousness and atypical behavior.

Recently it has been discovered that DDT also acts though hepatic enzyme induction. It induces the liver to produce enzymes; one of the activites of these enzymes is the hydroxylation of the steroid sex hormones. The resultant hormonal inbalance creates profound and unpredictable results. Estrogen, for example, controls calcium metabolism. The California brown pelican failed to breed in 1969 because its egg shells were so thin they collapsed when the birds tried to incubate them–DDT had disrupted their calcium metabolism.

The unfortunate thing about chlorinated pesticides is that they become concentrated in our environment. DDT is soluble in water in amounts of only 1.2 parts per billion. It is very soluble, however, in fats? thus DDT in the soil, rivers or oceans attaches itself to the nearest biological material or rapidly becomes adsorbed on particulate matter. Some California water contains 78 ppm DDT, 100,000 times the dissolved concentration.

Once DDT is dissolved in living material it passes up the food chain. Concentrations of 100 to 1,000 ppm cause death in birds and lesser amounts are fatal to invertebrates. Brine shrimp are killed by concentrations of 10^{-6} ppm. Probably the most endangered species are the birds of prey–the falcons, eagles and hawks. The case against DDT is well documented.

The classic example of movement and concentration of DDT in food chains is Clear Lake, California. After the lake was sprayed to remove insect pests, the DDT become concentrated in plankton. Small fish eating the plankton accumulated greater amounts of DDT. Finally, the Western grebe–a loon-like bird–ate the small fish. The results were disasterous to the reproductive cycle of the grebes.

This brief, partial resume of the DDT story illustrates the overall effect chemistry has produced on society. We now enjoy the benefits–no malaria, longer life expectancy, adequate food supplies, etc. In the process of getting these benefits, however, we became afflicted with the serious problem of environmental deterioration–contaminated water, contaminated food, destruction of our wild life, etc. Let me comment briefly on several specific effects.

1. The first is the *great public awareness of the effects of unlimited use of chemicals on our environment.* This has changed the role of chemists in society. Using the DDT story as our example, we find that many laws have been passed to regulate its use. Some states such as Arizona and Michigan have banned its use completely; the federal government has passed laws establishing maximum allowable DDT contents in our foods. What role have chemists played in the formulation of these laws? Consider the unknown chemist working in some analytical laboratory who decided that 0.7 ppm is the maximum concentration of DDT that should be allowed in meat. I am certain he did not realize the international implications of his work. His data were used as the basis for Federal regulations. When made aware of these regulations, the governments of Australia and New Zealand had to enact legislation restricting the widespread use of DDT in their countries. This was necessary so that the meat producers could meet the 0.7 ppm standard required for meat importation into the U.S. Their balance of trade depended on 0.7 ppm. This might not be the best example, but I am sure you get the point. Never before has it been so important for chemists to be aware of the implications of their work on society.

The public now demands action on the part of chemists to clean up pollution. Chemists are no longer a group of dedicated people working in isolated laboratories completely oblivous to society; we are now recognized as those bad–or good–guys who play a major role in the fate of our society.

2. The second development is the *new awareness of society concerning the effect of chemicals on their health.* People are now seriously concerned with the dangerous concentrations of DDT and other chemicals in their foods. Many want to return to the good-old-days when people ate natural unadulterated foods–the days when the average lifespan was 40 years and mosquitoes, flies and lice lived to ripe old ages. If DDT is dangerous to mammals, how about those approximately 400 chemicals that are mixed with our foods: mold inhibitors, coloring agents, bleaches, moisturizers, antioxidants, thickeners, thinners, emulsifiers and preservatives. Are we entering an era of antichemical McCarthyism?

Here is a list of a few interesting compounds. The first is 5-vinyl-2-thiooxazolidone-l. It is toxic to humans. It is found in rutabaga, turnip, kale, brussels sprouts, cauliflower and broccoli. The second is 3,4-dihydroxyphenylalanine, dopa. It causes a form of toxicity called favism. It is found in certain beans. Phytic acid is injurious to health because it interferes with the assimilation of iron and calcium. It is found in whole wheat, oatmeal and other cereal grains. Throbromine and caffeine are considered dangerous prescription drugs, but we consume them in our cocoa and coffee.

What things should be investigated? It took us 20 years to get the information on DDT (and this isn't complete); can we wait until every chemical is thoroughly checked until we use it? According to Patrick McCurdy, "What is needed is a liberal dose of balance and perspective along with a shot of just plain common sense."

3. The third effect of chemistry on our society has been *the creation of a need for more chemistry.* In particular, I am referring to the ever increasing need for more research, both fundamental and applied. Since I am using DDT as my example, I should mention a few things that are being done in the effort to cure the pesticide problem. I will give only two chemical examples.

Marvin Beasley, a chemist, was trying to make the iron salt of benzoic acid; what he got was a black sticky mess. A typical organic chemist might have discarded the gunk and proceeded to another synthetic method, but not Dr. Beasley. On further investigation he found that the black stuff was actually a polymer formed from the carboxylic acid and the iron, catalyzed by an aldehyde impurity. Further investigation disclosed the fact that the polymer would degrade slowly when in contact with water with the release of the original acid and hydrous ferric oside; the rate of degradation depending on the degree of polymerization. These polymers can be prepared from practically any carboxylic acid compound including 2,4-D, 2,4-T, etc. The controlled release of these herbicides is now possible; these polymers act as chemical metering pumps.

Probably the biggest cause of pesticide pollution is due to overuse of these chemicals and the necessity of constant reuse due to the removal of the pesticides by rain waters. Polymers can solve both these problems. A single application of l lb or 2,4-D per acred has effectively controlled weeds on Kansas grazing land for over a year. No migration of the herbicide was detected and the slow release limited the amount in young weeds to an unmeasurable level too low to be harmful to grazing animals.

Gravel coated with a herbicidal polymer and placed in a stream released the herbicide slowly but in quantities sufficient to control selected plants without affecting fish or wildlife. A polymer herbicide coating around soluble fertilizers can control both the release of the fertilizer and the herbicide. Water pollution is prevented since there is no run-off during rains.

Another possible solution to the pesticide problem is found in garlic. Some people eat nothing but organically grown, natural foods. Fortuantely, garlic is an important part of some of these diets. Extracts prepared from garlic possess a high pesticide activity. Not only that, garlic has antibacterial, antihelminthic and antiprotozoal properties. It also inhibits the growth of various tumors, acts as a diuretic and carminative agent; it shows a broad spectrum of activity against gram positive, gram nagative, acid-fast bacilli and fungi pathogens.

The major problems which chemistry has given to society can be solved. More chemistry is one answer. What is required is the complete cooperation of all industrial firms, government, unlimited financing and a major emphasis on the education of all people on the importance of science.

Let me conclude by quoting Philip Handler, National Academy of Science president. "Alarmed voices advocate retreat from our technological civilization as if life had been better in some bygone age when our ancestors lived closer to nature than do we, desiring a return to good old days that never were. For my part, I much prefer that we attempt to manage our technological civilization yet more successfully, remedying the errors of the past, building the glorious world that only science-based technology can make possible."

ENVIRONMENTAL ASPECTS IN CHEMISTRY COURSES

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Presented to the Chemical Technology Programs Section, 25th Two-Year College Chemistry Conference, Catonsville Community College, February 6, 1971.

Pollution of man's environment has become a common concern of young and old alike. It has been found that using applications of this theme in the teaching of chemistry can enhance the instructional program. The main objectives of this are to:

1. Increase student motivation, enthusiasm and involvement.
2. Make chemistry more relevant to the everyday world and to the needs of the student.
3. Teach the importance of sampling technique and taking a representative sample.
4. Teach basic analytical techniques using environmental examples.
5. Teach basic facts about the composition of the world around us, i.e. air and water.
6. Make students aware of a current and pressing problem that will face them on the job and as citizens.

A program involving environmental aspects may be implemented in several ways. Some of these are:

A. Presenting extensive material about environmental problems during the chemistry class.
B. Making laboratory assignments related to environmental studies.
C. Having students choose environmental topics for special reports and projects.
D. Having the entire class work on a large environmental project related to a particular course.

Each of these methods has been attempted in my classroom at Delaware Technical and Community College. The results were as follows:

1. Method A was the least effective in motivating students. The approach may be too academic.
2. Method B was found to be relatively effective and helped make the lab work in analytical courses more interesting.

3. Method C was effective in getting the students to work independently on assigned topics. It was found that the students would put in a considerable amount of time in the lab aside from the assigned times. One student presented a paper on such a topic at the 6th Middle Atlantic Regional Meeting.
4. Method D was probably the most rewarding of the above methods. A class in instrumental analysis did a comprehensive study of the water quality of a nearby river. As a result of this study several potential dropouts received the motivation to continue their studies and the students and college received considerable publicity from the local news media. This publicity was instrumental in obtaining jobs for two of the students.

It can be concluded that environmental aspects, if properly implemented, can be an asset to any chemistry course and to a chemical technology program in particular. The benefits are quite extensive and range from student motivation to job placement.

A brief description of our study of water quality in the Brandywine River follows.

Introduction

Fifteen samples were taken along the Brandywine River from Chadds Ford, Pennsylvania, to the junction of the Brandywine and the Christiana Rivers.

The sampling was done on "Earth Day," April 22, 1970 at about 10:00 a.m. The purpose of the study was to determine the chemical quality of the water by checking pH, nitrate, fluoride, cyanide, chloride and phosphate content.

Sampling Technique

The fifteen samples were assigned numbers in a random fashion. Each sample was taken in a 150 ml glass bottle. The samples were taken about five feet off shore at a depth of 1 to 2 feet.

Location of Samples

The location of each sample taken is given below. The sample numbers are arranged in geographic order from Chadds Ford to Wilmington.

Sample No.	*Location*
10	Junction of Route 1 and Brandywine River
8	Smith's Bridge
7	Thompson's Bridge
1	Below waterfall at Doeskin
11	Bridge at Doeskin
2	100 years past Doeskin Bridge
4	Tyler-McConnell Bridge
14	Rising Sun Road Cross-over
9	Rockford Tower
3	200 years downstream from Rockford Tower
13	200 yeards upstream from Bancroft
12	Augustine Bridge
5	Brown Technical High School
6	Just before 12th and Dure Streets
15	150 yeards before Junction of Brandywine and Christiana

Chemical Tests

The chemical tests were performed as follows:

Fluoride, Cyanide, Chloride–Orion solid state ion selective electrodes with an Orion 401 meter.
Nitrate–Orion liquid ion exchange ion selective electrodes with Orion 401 meter.
Phosphate–Colorimetric determination using ammonium vanadate and ammonium molybdate reagents with a B & L Spectronic 20.
pH–Orion 401, pH meter.

Results

Chemical Test	*Sample Number*														
	10	8	7	1	11	2	4	14	9	3	13	12	5	6	15
pH	6.69	6.71	7.09	7.19	7.00	6.78	7.12	6.68	6.50	6.90	6.75	6.70	6.60	6.79	7.40
Nitrate ppm	49.3	28.1	21.3	42.5	23.8	34.0	42.5	70.6	28.1	34.0	34.0	42.5	39.1	39.1	39.1
Fluoride ppm	.185	.135	.138	.135	.135	>.1	.250	.100	.100	.135	.135	.100	.135	.135	–
Cyanide ppm	.29	2.88	3.10	.68	4.2	>.1	>.1	.61	.104	.45	.29	.39	>.1	.32	.29
Chloride ppm	70.1	42.2	42.2	33.0	28.5	31.2	39.3	58.4	42.2	45.0	21.0	37.6	31.2	28.5	41.0
Phosphate ppm	–	15.5	–	5.20	–	8.8	12.4	–	10.0	–	13.0	10.0	10.7	11.0	16.8

Note: The results above in parts per million were measured in concentration using concentration standards.

Pollution Equipment References

1. LaMotte Chemical Products
Chestertown, Maryland 21620–Complete water testing kits

2. Milliport Corporation
Bedford, Massachusetts 01720–Environmental Pollution Analysis System

3. Hach Chemical Company
Box 907, Ames, Iowa 50010–Test kits for Ecology/Pollution studies

4. Soiltest Inc.
2205 Lee Street, Evanston, Illinois 60202–Instruments for detecting and preventing water pollution

5. Research Appliance Company
Allison Park, Pennsylvania 15101–Instruments for pollution detection

6. Lovibond of American, Inc.
870 Willis Ave., New York, New York 11507–Colorimetric testing equipment and chemicals

7. Scott Scientific Inc.
P.O. Box 2121, Fort Collins, Colorado 80521–Chemical water pollution test kit

8. Pollution Equipment News
P.O. Box 2121, Philadelphia, Pennsylvania 19141–Free subscriptions available

CHEMISTRY AND THE FUTURE OF OUR SOCIETY

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Presented at the Symposium on the Interrelationship of Chemistry and Our Society, 26th Two-Year College Chemistry Conference, Los Angeles, March 26, 1971.

Cities are at once the centers of good and bad, of progress and pollution, of human inventiveness and smog. Urban centers like New York City and Los Angeles are at once the focus of society's hope and the focus of society's fears. Chemistry plays an important role in both the hope and the fears.

Before we look at "chemistry and the future," let us look briefly at chemistry and the past. There are three features of chemistry in the past that I should like to select for your attention.

1. Chemistry extends back to the beginnings of time on our planet, 5×10^9 years ago. Chemistry began to exert its influence on man long before there was man. Chemistry worked *alone* to experiment with new elements and compounds *without* the aid of chemists. When man finally came, he was innocent of the world of chemistry. Compared to the billions of years of chemis*try*, chem*ists*, even today, are young. On the cosmic calendar chemists are newcomers. They do their thing with youthful exuberance in a world of ancient chemistry.

2. The second feature of age-old chemistry to which I call your attention is this: there is a certain "givenness" about chemistry. Hydrogen, for example, the simplest atom, has a built-in "given" chemical potential to become more complex. Hydrogen has the "given" chemical potential to become helium and helium has the "given" chemical potential to become carbon and nitrogen and oxygen. Hydrogen has the "given" chemical potential to become eventually all the elements that are known to exist.

Moreover, on the primitive earth, hydrogen, methane, ammonia and water had the "given" chemical potential to become amino acids and sugars. Since the Miller and Urey experiments in 1953, many other clues have been collected pointing to the abiogenic origin of organic compounds.

3. A third noteworthy feature of chemistry in the past is this: the givenness of chemistry gave rise to *life*. Inorganic and organic chemicals in the primitive oceans gave rise to self-reproducing systems that we recognize as living forms. The givenness of chemistry resulted in biochemistry. The complexity of biochemistry led to *better* life; it achieved the critical mass and size that lead to the consciousness and freedom and responsibility found in man.

With such a *past*, what of the *future* of chemistry? Now that man is taking his place as a chemist in the chemical system in which he lives, now that he is learning to manipulate and control the chemistry of his environment and even the chemistry of his own body, will man live up to the promise made by chemistry when it was alone without human chemists? Chemistry gave rise to life; will chemists produce a better life?

In 1965 Charles Price, then President of the American Chemical Society, challenged the chemists, and indeed the whole population of the U.S.A., to accept as a national goal the chemical synthesis of life. This goal, he argued, may well be as close to us now as atomic energy was in the 1920's or as moon walks were in the 1940's. Dr. Price quite naturally concludes that chem*ists* should produce life, just as chemis*try* in the past did. When decisions for the future are made, chemists should be on the side of life.

Some people tend to face the future with a pessimistic outlook. For some, time is an arrow pointing downward. In the Greek view of history, time is cyclic; history is like a circle: it does little more than repeat itself. Progress is a delusion. In the current recession in the chemical industry it is easy to be a pessimist. Moreover, we have come to appreciate more and more how man encumbers his planet by living here. In 1969 the ACS issued a report, *Cleaning Our Environment: The Chemical Basis for Action.* This report gives details about problems in the pollution of air and water, in the disposal of solid wastes and in the use of pesticides.

Rather than dwell on the pessimistic side, I believe there is a basis for optimism. On the one hand we have the "givenness" of chemistry. Chemistry is old, but it is still here; it is predictable. Its predictable "givenness" makes for human security. On the other hand we have chemists with the exuberance and enthusiasm of youth. They have the ability to take advantage of the predictability of chemistry.

One of the leading optimists of this century, Pierre Teilhard de Chardin, viewed time *not* as an arrow pointing downward *nor* as a circle pointing nowhere in a senseless repetition of former folly, but as a spiral pointing upward that converges at a point where science and society are brought together in an unprecedented oneness. In this vision of the future, urbanization is a natural and necessary development. The growth of cities brings together a concentration of human genius that can achieve the critical mass needed to solve human problems. Chemists must play a role in the unifying of mankind.

There are a number of ways in which chemists figure in the future of our society. Closest at hand is the practical task of making our cities livable. There is a supplement to the ACS report on *Cleaning Our Environment*. This supplement lists 26 priority recommendations as a chemical basis for improving the quality of our environment. The recommendations are worthy of the attention of all of society, but especially of us as chemists. The first recommendation, for example, is that "An intensive study should be made of air pollution in a single city in all its ramifications–chemical meteorological and biological. The study should be made in an integrated fashion; if it is done piecemeal, the value of the data will be far less, and the ultimate cost of acquiring the necessary information will be far more."

Success in the pollution field, complete success, will require the strenuous effort of many. Chemists can contribute to the unity of man by tackling such great projects. It is essential to understand that there is a value and worth in the human effort to improve the quality of life, just because the effort is human. The quality of our chemical endeavor contributes in proportion to its excellence to the unfinished task of "building the earth."

Chemists also contribute to the unity of man through chemical education. There is something about truth that necessarily brings about unity. The teaching of chemistry takes its place among the liberating experiences taht draw men together. Anything less than excellence in chemistry teaching is a disservice to mankind.

There is yet another important way in which chemists can contribute to the improvement and eventual unity of mankind: by the chemical improvement of his own body, the human body. This is a topic of special interest to me. It is discussed at some length in a book of mine published in 1967 (*Man's Intervention in Nature*, Hawthorn Books, Inc., New York). Chemists and biochemists can and will have an impact on medical care and on the genetic future of mankind. The improvement of the environment is called "euthenics"; the improvement of medicine is called "euphenics"; and the improvement of the inherited traits of man's progeny is called "eugenics." All three of these, euthenics, euphenics and eugenics, are open to the influence of chemists.

The moral implications and consequences of such applications of chemistry are enormous. On one extreme there are those who counsel an "anything goes" approach in changing the nature of man. Skinner, a Harvard psychologist, thinks that we must change the biological basis of pleasure. At present man gets pleasure from things calculated to help him survive in a jungle: food, sex and hurting his fellowman. In a city, Skinner argues, man needs to get pleasure from other pursuits–and therefore the biological and chemical mechanisms that result in pleasure must be understood and changed to help man survive in the city. On the other extreme are those who feel that nothing–nothing at all–may be changed in the inheritance of man. Such things are outside man's competance.

There is a less extreme approach that foresees and welcomes *some* intervention in the chemistry of man's body, for example, the curing of inherited diseases. The approach of critical openness to change is preferable. Although there is the danger of Huxley's *Brave New World* type of society, when the day comes that enough chemistry is known to predict with some precision the effect of "genetic surgery," it will be morally permissible with proper safeguards to improve the gene-pool of the human race in this way. To rid mankind of inherited disease will be an instance of chemists using the "givenness" and predictability of chemistry to improve the quality of life, to eliminate the burden of deleterious genes from future generations and thus to allow man to be more at one with himself and with his fellowman.

A SHORT COURSE FOR TEACHERS

BIOCHEMISTRY

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Presented as a short course to the annual Asilomar Conference of the California Association of Chemistry Teachers, Asilomar, California, August, 1971. Although missing the important discussions that followed the lecture, it is hoped these lectures will stimulate improvement of biochemistry discussions in chemistry classes.

Lecture I. Characteristics of Living Systems

There is no reason to doubt that all laws and principles of physics and chemistry apply to living systems. But a very important distinction must be kept in mind–life is *consistent* with the principles of physics and chemistry, but its characteristics cannot be *predicted* from those principles.

The aim of this course is to survey some aspects of the chemistry of living systems. To supply a basis for later discussion, this lecture will be devoted to consideration of the nature of living systems, and some of the ways in which they differ from non-living chemical systems.

The most apparent chemical property of living systems is *complexity*. Each cell, which usually has a volume between 10^{-6} and 10^{-12} ml, contains several thousand metabolic intermediates and several thousand protein catalysts (enzymes). Some of the compounds are themselves extremely *complex* in structure.

A more striking property is *order*. Any non-living mixture of several thousand reactants and several thousand catalysts would rapidly degenerate into a useless mess. A living organism maintains itself, grows, and reproduces. The correlation and control that make this possible is one of the most interesting aspects of the chemistry of life. A living cell is a system of very low entropy and very high free energy and in physical–chemical terms is a very unlikely system; yet it is strongly stabilized.

In studying any aspect of nature, we must use not only appropriate methods, but also appropriate ideas. There is no function or coordination in the non-living world (except in devices made by living organisms), and so the ideas of *function* and *purpose* have no place in general physics and chemistry. Unfortunately, some textbooks generalize too far, and say that "why" questions or ideas of function have no place in science. That is not a valid generalization; it applies only to the areas of science that deal with inanimate objects. In biology, everything is functional and many of the most important questions are "why" questions. We must consider this fundamental difference, and the reasons for it, before discussing the chemical processes themselves.

We should first repeat that all of the principles of ordinary chemistry apply also to living systems. Life does not have its own special type of chemistry or a different set of chemical laws–it merely is ordinary chemical process arranged in a highly ordered and stabilized way. As an analogy, combustion chemistry is essentially identical whether gasoline is burned in an open dish or under controlled conditions in an automobile engine, yet one is controlled and without function, whereas the other is controlled and functional. The relation between these two ways of burning gasoline: not a difference in underlying chemistry, but a difference in the way that chemical processes are coupled to other chemical or physical processes.

In studying or describing living systems, we cannot separate the biological aspects from the chemical. That is a false distinction, based on the way that science happened to develop historically. All of the properties of an organism are closely integrated: the chemical processes are correlated to serve biological functions and the biological processes are based on chemistry.

All biological function is the result of *evolutionary design*. The greatest generalization in biology is the realization that all organisms have change throughout their history, and are still changing, as a result of *mutation* and *selection*. Random mutation, with survival of any changes that work better, is a trial-and-error process much like engineering design. The products of evolution (living organisms) are as functional as anything designed by man.

Compare the shape of a continent with the shape of an organism. It is scientific to ask what were the geological processes that led to the formation of Florida or Baja California, but it would be meaningless to ask about the *functions* of these appendages. In contrast, the legs and wings of a butterfly are obviously totally functional. They have developed by way of a long series of small advantageous changes, selected from among a much larger number of harmful changes. Any component of an organism should be considered, like a spark-plug or a fan belt, with its function in mind. If we study it merely as an object (or study a biological reaction merely as a reaction) we will miss most of its significance.

Much time has been wasted by some biologists and philosophers on meaningless questions such as "Is the whole greater than the sum of its parts ?" This is sometimes posed as the great philosophical dilemma of biology. In fact it is simple nonsense. The question has no definite meaning and hence no clear answer, but nothing either mysterious or specifically biological is involved. Is water greater than the sum of H_2O and O_2? It is certainly different from a mixture of the two gases. Is a bus greater than a pile of the parts that make up a bus? Is an organism greater than the sum of the compounds that make it up? Your answer must be the same as your answer to the bus/parts question. Whether it is "yes" or "no" is a matter of your interpretation of the words—the question has no scientific or other real meaning. In both cases the *organization* of the whole (the bus or the organism) allows it to *function*. The pile of parts or the random mixture of compounds has no organization, no correlation, no control, and no function. In both cases *function* has been added as a consequence of functional organization. The chemical composition of the organism is far more complex than that of the bus and its functional capacities are far greater, but the principle is identical. To return to our first paragraph, all of the properties of the bus or the organism are fully *consistent* with the chemical properties of the component parts, but one could not *predict* the bus from the properties of various ores and organic precursors any more than he could *predict* an amoeba or a daisy or a man from the properties of C, H, N, and O.

Spatial Organization

Not only are the components of a cell, such as enzymes, highly specialized to serve particular functions, but they are often organized into functional subsystems, or organelles, within the cell. Here we can consider only a few types of organelles.

The *nucleus* contains the hereditary material, DNA. It may be thought of as the *library of the cell*, containing the blueprints for all of the cell's machinery, as well as Xerox machines that allow it to copy individual blueprints to send out for production of individual machines (proteins) and also to copy the whole library when the cell divides.

Mitochondria contain the enzymes for the oxidation of pyruvate or acetate, which are produced in the cytoplasm from carbohydrates and fats. The electrons from these oxidations are transferred to O_2 and on the way pass through a series of reactions in which adenosine triphosphate (ATP) is regenerated. ATP is used in almost every energy-requiring process in an organism, from synthesis of intermediates and proteins to muscle contraction and pumping compounds across membranes. Thus the mitochondria are often called the powerhouses of the cell. Bacteria do not have nuclei or mitochondria. The DNA is naked in the cytoplasm, and the enzymes that would be in the mitochondria of other cells are associated with the membrane that surrounds the cytoplasm.

Ribosomes are involved in protein systhesis. They may be thought of as general-purpose machine shops, able to turn out any kind of machine if supplied with the appropriate blueprint (messenger RNA). DNA, RNA, and the synthesis of proteins will be considered later.

Chloroplasts, in photosynthetic organisms, contain chlorophyl, which absorbs sunlight, and all of the machinery needed to use this captured energy in the synthesis of sugar from CO_2 and H_2O. They are essentially complex synthetic laboratories run by solar batteries.

There are many other specialized organelles in cells of different types.

The parts of higher organisms are, of course, highly specialized on a larger scale. The specialized functions of external parts like legs, wings, and teeth are obvious; so are those of major internal organs such as heart, brain, stomach, or intestines. Many organs, large and small, are specialized for purely chemical functions. The liver carries out much of the body's synthetic activities and regulates the level of blood glucose, among other things. The pancreas makes digestive enzymes for use in the intestines. The many endocrine glands, such as thyroid, adrenals, and pituitary, produce hormones that participate in regulation and control.

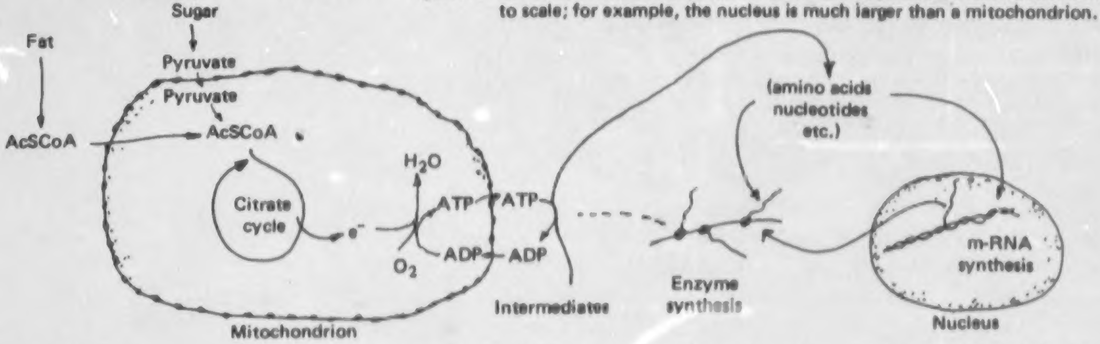
Biological Steady State

The essence of life is ordered complexity. The order is not static, but dynamic. The rates of chemical reactions in living cells are high. Thus, a living cell is not at or near equilibrium, but in a dynamic steady state. Although there are examples of steady states in the non-living world, such as flowing streams or candle flames, they are relatively rare. The stream is at a steady state only because water is entering it at a steady rate. It is not a controlled system and has no way to maintain its rate when conditions change. A living cell, in contrast, is highly regulated, and maintains its biological steady state or *homeostasis* even when changed drastically.

Lecture II. Metabolic Function and Metabolic Coupling

Like any other complex functional mechanism, a living cell can be considered in terms of functional blocks. Energy is provided by the oxidation of foods (or by other breakdown sequences in anaerobic organisms), and is used in biosynthesis, mechanical work, pumping materials across membranes, and the like. These processes are functionally, and in many cases structurally, distinct. Figure 1 is a simplified schematic diagram of some of these functional sequences.

Figure 1: Schematic representation of some metabolic processes. The sketch is not to scale; for example, the nucleus is much larger than a mitochondrion.



In a typical aerobic organism, sugar provides both (a) the intermediates for biosynthesis of the cell's other components and (b) pyruvate, which is oxidized to yield the energy for the syntheses. Analogously, a petrochemical plant may make a wide variety of products from petroleum, while burning some of the petroleum to get energy to run the plant.

The conversions of sugar to pyruvate and of fat to an activated derivative of acetic acid, acetyl coenzyme A, are carried out in the cytoplasm, which is the general semi-liquid matrix surrounding the nucleus and mitochondria. Pyruvate and acetyl coenzyme A are oxidized to CO_2 in the mitochondria, and as each pair of electrons is transferred to O_2, 3 moles of ADP are converted to ATP. Provision of ATP is the primary function of the oxidation of foods, since ATP is used to power nearly every energy-requiring process in the cell.

The Kreb's Cycle

The cyclic series of reactions by which acetyl coenzyme A is oxidized is called the Krebs cycle or citrate cycle. This cycle also produces some of the starting materials needed for biosyntheses. ATP and these intermediates move into the cytoplasm where they are used, along with intermediates made there, in the biosynthesis of nearly all of the cell's constituents. Nucleotides move into the nucleus, where they are used in the synthesis of many types of messenger RNA, each copied from a specific part of the DNA, and each containing the information for synthesis of one or more specific proteins. The messenger RNA moves to the corresponding proteins (most of which are enzymes) from amino acids. Each of the many steps in the biosynthesis of amino acids and nucleotides, as well as every other chemical reaction in the cell, is catalyzed by a specific enzyme. Thus biological chemistry is cyclic on many levels. As one example, enzymes are needed to make amino acids, but amino acids are needed in the synthesis of enzymes. Also, enzymes are needed to make nucleotides, which are needed to make messenger RNA, some of which carry the information needed for production of the enzymes needed to make nucleotides.

Nucleic acids and the synthesis of proteins will be discussed later. For the present, we will consider metabolic function, and coupling between chemical sequences, in general terms.

The living cell has often been discussed in terms of an economic analogy. In these terms, it is clear that the cell uses a currency system rather than a barter system. The advantages are similar to those in economics and the main advantage is flexibility. A shoemaker who sells shoes for money can then buy what he wishes; he need not waste time looking for someone who can supply bread or leather, for example, and who needs shoes. Similarly in the cell, the use of ATP as a currency means that all energy-requiring processes can be linked to all energy-releasing processes, so that energy can be obtained where available and used where needed. There is also a great saving in the number of enzymes required.

ATP is the universal currency of the cell. Translated into chemical terms, that statement means that ATP stoichiometrically couples all metabolic reaction sequences. In a few cases, the coupling is indirect, but in most cases ATP is a direct coupling agent. (Most of the exceptions involve synthesis of macromolecules.)

Some textbooks speak of oxidative reactions releasing energy to drive other reactions. Such statements are obviously chemically meaningless. *A reaction or reaction sequence can drive another only if they are chemically linked by specific stoichiometric chemical reactions. This stoichiometric coupling is the metabolic function of ATP.* As in any price system, we may speak of the cost of an intermediate or the cost of carrying out a conversion. We will use molecules or moles of ATP, rather than dollars, in our pricing. Thus, the complete oxidation of a mole of glucose to CO_2 causes the production of 36 moles of ATP from ADP. Each mole of acetyl coenzyme A that is oxidized in the Krebs cycle leads to the production of 12 moles of ATP. Similarly, every metabolic sequence involves the production or consumption of a fixed amount of ATP.

In the oxidation of glucose to CO_2, 12 pairs of electrons are lost. Ten of these are transferred to nicotinamide adenine dinucleotide (NAD^+), then to a flavoprotein, then probably to a quinone, and then through a series of iron-containing proteins (cytochromes) to O_2. At three steps in this series, the electron transfer reaction is coupled obligately and stoichiometrically to the production of ATP from ADP. This overall process is termed oxidative phosphorylation or electron transfer phosphorylation. (The other two pairs of electrons are transferred directly to a flavoprotein, bypassing NAD. They also participate in electron transfer phosphorylation).

NAD^+, also called diphosphopyridine nucleotide (DPN^+), is a rather large molecule. The group that undergoes oxidation and reduction (a pyridine ring) is at one end. The other end is an AMP group, which is apparently concerned mainly with specificity of binding to the right enzymes. The cytochromes contain iron in a heme group as in the blood pigment, hemoglobin. However, the associated proteins change the properties of the heme so that in hemoglobin, iron (II) binds an O_2 molecule reversibly and resists oxidation, while the iron of the cytochromes is readily interconverted between the iron (III) and iron (II) states and has little tendency to bind O_2.

Many biosynthetic sequences contain steps in which the substrate is reduced. In nearly every case, the reducing agent is nicotinamide adenine dinucleotide phosphate (NADP), also named triphosphopyridine (TPN). This compound differs from NAD only in the presence of an additional phosphate group in the enzyme-coding part of the molecule. Nearly all of the enzymes that use these electron carriers are completely specific, using either NAD or NADP, but not both.

The distinction between the metabolic roles of NAD and NADP is a very striking illustration of evolutionary design. NAD is involved in reactions in which substrates are oxidized, and NADP in reactions in which substrates are reduced. In the living cell, NAD exists largely in the oxidized state, while NADP is largely reduced. This obviously facilitates their metabolic functions. This differentiation is possible only because the enzymes are designed to distinguish between the two compounds. The mechanisms by which NADP is kept highly reduced are not yet fully understood, but the biological advantages are obvious.

It is clear that electron-carrier compounds like NAD and NADP also serve as stoichiometric coupling agents, and supplement the primary coupling by ATP.

Lecture III. Metabolic Regulation

Nearly every metabolic conversion can also be carried out in the opposite direction. Thus, CO_2 and H_2O can be converted to sugar (photosynthesis) and sugar can be oxidized to CO_2 and H_2O (respiration). Fats are metabolized to acetyl coenzyme A, but fats are also sythesized from acetyl coenzyme A. If the same paths were used in both directions, such a conversion would necessarily pass through equilibrium each time the direction changed, and metabolic sequences could be expected to hover sluggishly near equilibrium. Actually this is far from the case. Metabolic reactions are capable of very high velocities, and metabolic sequences are seldom, if ever, close to equilibrium.

One of the characteristics of metabolic chemistry that one would be least likely to predict from chemical principles alone is that almost every case of oppositely-directed conversions involves a separate pathway for each direction. At least some, and frequently all, of the enzymes that participate in the "forward" direction are not involved in the reverse. For example, 8 moles of acetyl coenzyme A can be converted to one mole of the C-16 acid palmitate, a common constituent of fats; conversely, a mole of palmitate can be broken down into 8 moles of acetyl coenzyme A. But all of the intermediates, and hence all of the reactions and all of the enzymes, involved in the synthesis are different from those in the breakdown. Perhaps the most surprising chemical feature of this situation is that *both the synthesis of palmitate from acetyl coenzyme A and its breakdown to acetyl coenzyme A are simultaneously thermodynamically favorable.* One of the most important features of the universal coupling of reaction sequences by ATP is that the *stoichiometry of ATP coupling is adjusted to make nearly every metabolic sequence unidirectional in the living cell.* Because more ATPs (or equivalents) are needed for the synthesis of palmitate and acetyl coenzyme A, the equilibrium of the degradative sequence will lie in the direction of breakdown.

If the same reactions were used in both directions, a single equilibrium constant would apply, and the sequence could be reversed only by drifting across equilibrium. Reaction rates in the vicinity of equilibrium must be relatively slow. Also the concentrations of reactants and products would necessarily be quite different during synthesis than during breakdown. This would work against chemical stability, or homeostasis. Both of these difficulties are overcome by the use of separate oppositely-directed unidirectional reaction sequences. Such sequences are relatively far from equilibrium at all times, and can be turned on and off as the needs of the cells change. Thus metabolic response can be extremely flexible.

In the absence of effective control mechanisms, each pair of oppositely-directed sequences would constitute what has been called a "futile cycle"–a short-circuit of the cell's metabolic energy. To illustrate again with the palmitate-acetyl coenzyme A conversion, the equations for the two processes are:

$$\text{8 acetyl CoA} + 7\ \text{ATP} + 14\ \text{NADPH} + 14\ \text{H}^+ \longrightarrow$$
$$\text{palmityl CoA} + 7\ \text{ADP} + 7\ \text{P}_i + 14\ \text{NADP}^+ + 7\ \text{CoA} \qquad K > 1$$

$$\text{palmityl CoA} + 7\ \text{NAD}^+ + 7\ \text{F·Prot} + 7\ \text{CoA} \longrightarrow$$
$$8\ \text{acetyl CoA} + 7\ \text{NADH} + 7\ \text{F·Prot·H}_2 + 7\ \text{H}^+ \qquad K > 1$$

(P_i is orthophosphate; F·Prot and F·Prot·H_2 are the oxidized and reduced forms of a flavoprotein electron carrier.)

Since both sequences are thermodynamically possible, and the cell contains enzymes to catalyze all of the reactions of both, in the absence of regulation both would proceed, and the net reaction would be

$$7\ \text{ATP} + 14\ \text{NADPH} + 7\ \text{H}^+ + 7\ \text{NAD}^+ + 7\ \text{F·Prot} \longrightarrow$$
$$7\ \text{ADP} + 7\ \text{P}_i + 14\ \text{NAD}^+ + 7\ \text{F·Prot·H}_2 \qquad K \gg 1$$

It is obvious that the hydrolysis of ATP to ADP and P_i is a direct waste of the cell's energy. Less obviously, the oxidation of NADPH by NAD^+ and flavoprotein represents an equally serious drain. Evidently, these two sequences must not be allowed to occur at the same time. Similar considerations apply to almost every metabolic sequence in the cell. Thus unidirectional sequences make sensitive and flexible control both possible and essential.

Since the main function of breakdown or degradative metabolism is the regeneration of ATP from ADP and AMP, whereas ATP is converted to ADP or AMP in all synthetic or other energy-consuming processes, it is evident that metabolic regulation must respond to the balance among AMP, ADP, and ATP. The adenylate system is closely analogous to a storage battery–it accepts stores, and releases chemical energy. Thus we may speak of the charge of the adenylate system in a living cell just as we speak of the charge of a storage battery. In a lead storage cell, the reaction proceeds to the right when the cell is

$$2\ PbSO_4 + 2\ H_2O = Pb + PbO_2 + 2\ H_2SO_4$$

Correspondingly, in the adenylate system the overall reaction accepts energy by proceeding to the right and supplies energy in going to the left.

$$AMP + 2\ P_i = 2\ ATP + 2\ H_2O$$

This overall cell reaction is actually the sum of two separate processes but that does not affect the equilibrium or thermodynamic considerations.

$$2\ ADP + 2\ P_i = 2\ ATP + 2\ H_2O$$
$$AMP + ATP = 2\ ADP$$

In the lead cell, all 3 oxidation states of Pb are insoluble so the charge can be measured by the concentration of H_2SO_4, which is estimated from the density of the electrolyte. In contrast, all of the components of the adenylate "cell" are soluble, so that we must use the concentrations of AMP, ADP, and ATP themselves in estimating charge. From the equation for the adenylate system, it is evident that in a simple mixture of AMP and ATP the charge would be proportional to the mole fraction of ATP. From the last equation above, however, it follows that 2 moles of ADP can supply 1 of ATP. Thus, ADP must enter into the expression for charge of the adenylate "cell." The appropriate function is

$$\text{Energy charge} = \frac{ATP + 1/2\ ADP}{ATP + ADP + AMP}$$

This function is directly proportional to the amount of metabolically available energy stored in the adenylate system, and thus is closely analogous to the charge of a storage battery.

From many analyses of cells and tissues of a variety of types, we find that the energy charge in living cells is nearly always in the range between 0.8 and 0.9. That is, the adenylate battery is kept at about 80 to 90% of full charge. The constancy of this value is striking, especially since the total amount of ATP, ADP, and AMP in a living cell is so small that the battery would be fully discharged in about 1 to 2 seconds if charging were to stop suddenly while ATP-utilizing processes continued at a normal rate. It is evident that the charge can be so finely controlled only if there is what amounts to a very sensitive and effective voltage regulator. Unlike the voltage regulator in an automobile, the biological regulator must control the rate of discharge as well as the rate of charge of the battery.

Since all metabolic sequences either use or regenerate ATP, they must all be regulated by the charge of the adenylate "battery," if the charge of that battery is to be maintained at a nearly constant value. We must expect effects of the kind shown in Figure 2, where R indicates sequences in which ATP is regenerated, and U represents sequences that utilize ATP. It is evident that if enzymes respond in this way, the energy charge of the adenylate system will be strongly regulated. A slight decrease would increase the rates of sequences that regenerate ATP and decrease the rates of those that use it. A slight increase in the charge would have the opposite effect. In both cases, the result would be that the change would be resisted and the charge would be highly stabilized.

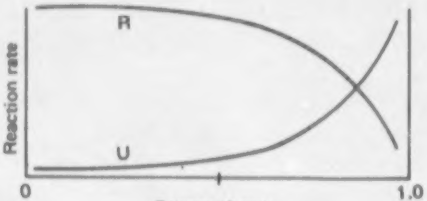


Figure 2: Typical responses to the adenylate energy charge of regulatory enzymes from metabolic sequences in which ATP is regenerated (R) and from sequences in which ATP is used (U).

Curves of the R and U types have been obtained when appropriate enzymes have been studied in cell extracts. In every case, the response was of the "correct" type on the basis of the metabolic function of the enzyme; that is, no R responses were obtained when U was expected, or vice versa. Thus, these properties of individual enzymes are entirely consistent with the observed stability of the energy charge in intact cells. In fact, a stable charge of about 0.85 was predicted on the basis of the enzymic studies before the analytical values were compiled.

Metabolic control by ATP, ADP, and AMP appears to be general, probably applying to all metabolic sequences. In addition, each sequence is regulated on the basis of its individual metabolic function. For example, the first step of each biosynthetic sequence is inhibited by the end product of the sequence. This is roughly analogous to a water-level regulating device. If the concentration of the product falls slightly, inhibition of the enzyme catalyzing the first reaction leading to its synthesis will be relaxed, and the rate of synthesis will increase. If the product concentration tends to rise, the rate of synthesis will decrease. Thus, the concentrations of these products will be stabilized.

In effect, the rate of production of each product is determined by two criteria: how necessary is the synthesis (what is the concentration of the product) and how easily can we afford to carry it out (what is the energy charge of the adenylate system).

Lecture IV. Properties of Enzymes

Many of the intermediate compounds in metabolism are rather reactive, capable of thousands of reactions beside those that are used in ordered metabolic sequences. How are undesirable side reactions avoided?

It appears that the main answer is: by simple dilution. Only a very small number of metabolites, such as ATP, occur in the living cell at concentrations approaching 10^{-2} M. A larger number, but still a small fraction (such as some of the intermediates in major pathways like the oxidation of sugar) are found at concentrations around 10^{-3} M. The concentrations of most intermediates are below 10^{-4} M, and those of highly reactive compounds, like keto acids, are in the 10^{-5} to 10^{-7} M range.

Consider a reaction between A and B. This may be relatively rapid under standard conditions (with each reactant at 1 M). If it is a simple first-order reaction with regard to each reactant, $v = k(A)(B)$. Thus, if each is at 10^{-5} M, the reaction velocity would be 10^{-10} times that at standard conditions. Hence, an amount of reaction that would occur in one second under standard conditions would require a little over 316 years at biological concentrations. It is clear that dilution is a very effective protection against undesirable reaction. It is equally clear that very good catalysts are required if desired reactions are to proceed rapidly at biological concentrations.

All biological reactions are catalyzed by enzymes, which are proteins. Like any catalyst, an enzyme affects the rate of a chemical conversion by supplying an alternate path with a lower energy barrier, as shown schematically in Figure 3. The vertical scale indicates the energy content per molecule, and the height of the barrier is the activation energy (E_a) that is required to permit the reaction to occur.

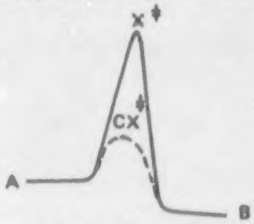


Figure 3: Energy profile for the uncatalyzed (solid line) and catalyzed conversion of A to B

Since the distribution of energy among molecules is exponential, the proportion of molecules having sufficient energy for reaction changes greatly with relatively small changes in E_a. At room temperature, a decrease of 5 kcal/mole in the value of E_a will increase the number of molecules capable of reaction by over 4000 times and, other things being equal, will cause the reaction velocity to increase by the same factor. A decrease of 10 kcal/mole will correspond to an increase by a factor of about 17 million. Thus, if a catalyst supplied a reaction path with an E_a of 15 kcal/mole, while E_a for the uncatalyzed reaction was 25 kcal/mole, this 40% decrease in activation energy could cause the reaction to go 17 million times as fast as the uncatalyzed reaction. Acceleration factors for enzymes are commonly from 10^8 to 10^{15}. These are large factors; as we have seen, 10^{10} seconds is about 316 years.

A catalyst, of course, cannot affect the *direction* of a chemical conversion; it can only cause more rapid progress in the thermodynamically favorable direction–toward equilibrium. But enzymes can and do direct metabolic sequences by selecting from among the thermodynamically possible reactions for each intermediate. If a compound has 10 possible reactions and one of them is accelerated by a factor of around 10^{12} by an enzyme, the others become totally insignificant. Thus, the highly specific pathways of metabolism are produced by diluting the intermediates to the point where all uncatalyzed reactions are slow and then selectively accelerating just these reactions that fit into an integrated pattern.

Enzyme Catalysis

Four common patterns of reaction velocity as a function of reactant concentrations are shown in Figure 4.

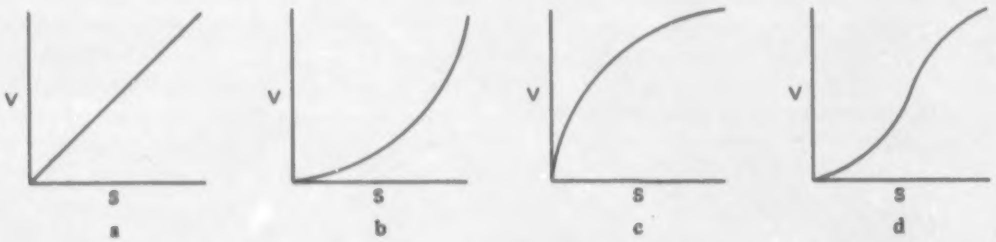


Figure 4: Patterns of reaction velocity as a function of substrate (reactant) concentration.

Curve a represents an ordinary first-order reaction, with velocity proportional to reactant concentration. It was noticed about 80 years ago that enzyme reactions typically give patterns like c, with velocity approaching a maximal value, rather than increasing indefinitely as in a. Since the maximal rate depends on the concentration of the enzyme, curves of type c imply that an enzyme contains a limited number of reactant sites; when they become saturated, no further increase in reaction velocity is possible. Recognition of this feature of enzymic catalysis led to what is termed the Michaelis treatment of enzyme kinetics.

A typical enzyme-catalyzed reaction may be written as

$$A + E \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} EA \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} EB \underset{k_{-3}}{\overset{k_3}{\rightleftharpoons}} E + B$$

where E is enzyme, A is reactant, B is product, and EA and EB are complexes in which A or B is bound at the catalytic site of the enzyme. It is assumed, on the basis of curves like c of Figure 4, that the actual chemical conversion of A to B ($EA \rightarrow EB$) is the slowest step. If this is so, E, A, and EA will be nearly at equilibrium during the reaction. Thus, as a close approximation, we may write the equilibrium expression $K_A = \frac{(E)(A)}{(EA)}$ for the first step. The enzyme is partitioned between free enzyme and the EA complex, so we assume that $(E)_T = (E) + (EA)$. Thus $K_A = \frac{[(E)_T - (EA)](A)}{(EA)}$.

If the second step is rate-limiting, as we assumed in order to explain curve c of Figure 4, the velocity of the overall reaction depends on this step, and $v = k_2(EA)$. When the enzyme is saturated with A, $(EA) = (E)_T$, so $V_m = k_2(E)_T$, where V_m is the maximal velocity. Substituting these values, we obtain $K_A = \frac{(V_m - v)(A)}{v}$ and rearrangement leads to the Michaelis equation,

$$\frac{v}{V_m} = \frac{(A)}{K_A + (A)}$$

A plot of this equation has the form of curve c, and K_A, called the Michaelis constant, is easily seen to be the concentration of reactant at which $v = 1/2\, V_m$.

Returning to Figure 4, **b** is the curve for a reaction of second or higher order; it indicates that the reaction velocity depends on the square or higher power of reactant concentration. It is clear that curve **d** combines the features of both **b** and **c**; that is, it corresponds to an enzymic reaction, with saturation of enzymic reaction, with saturation of enzyme catalytic sites, but one in which reaction velocity is proportional to the reactant concentration raised to a power higher than 1. Such a curve implies that more than one molecule of the reactant affects the rate of the reaction. Although a curve of this type was first described and discussed as late as 1956, this is now recognized to be a fairly common response, and to be characteristic of many regulatory enzymes.

Metabolic control of the type discussed earlier must depend on the properties of enzymes. Regulation on the basis of the adenylate energy charge or the concentration of an end product is obtained by direct response of an enzyme to the concentration of *effectors* or *modifiers*—the small compounds (such as AMP, ADP, ATP, or a biosynthetic end product) that serve as regulatory signals. An enzyme is a protein catalyst, but it is much more. Many enzymes are highly sophisticated control elements, capable of sensing the concentration of from one to six compounds, integrating them in a complex non-linear way, and changing conformations so as to produce the appropriate change in catalytic properties. The concentration of a modifier is sensed by means of a regulatory site at which the modifier binds. Such sites are presumably similar to catalytic sites. However, when a reactant binds it is activated for reaction; when a modifier binds, it causes changes in the conformation of the enzyme molecule that affect the properties of catalytic sites located some distance away on the enzyme surface. For most regulatory enzymes reactants also serve as modifiers; that is, when a reactant molecule binds at a catalytic site it is activated, and simultaneously the conformation of the enzyme at other catalytic sites is changed in such a way as to facilitate the further binding of reactant. This is the cause of curves of type **d** in Figure 4.

Figure 5 illustrates typical behavior of a regulatory enzyme.

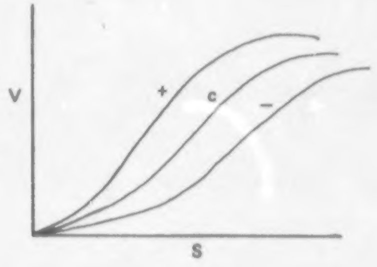


Figure 5: Velocity of a reaction catalyzed by a regulatory enzyme as a function of substrate concentration;

c = control; + = positive modifier; – = negative modifier.

The effect of a bound substrate on other catalytic sites is responsible for the S-like shape of the curves. The response of the enzyme in the absence of the modifiers (curve c) is changed on the addition of modifiers. A positive modifier (curve +) increases the affinity of the enzyme for the substrate, and thus allows it to compete more favorably with other enzymes using the same substrate; a negative modifier (curve –) has the opposite effect. The S-shape (sigmoid shape) of the curve allows the rate to respond about equally sharply to changes in concentration of reactant whether a modifier is present or not.

Metabolic regulation appears to depend mainly on partitioning of intermediates between competing pathways. Changes of the kind shown in Figure 5 affect this branch-point partitioning, and thus determine how much of the cell's available material is used in each metabolic sequence.

Figure 5 is similar to the characteristic curves of a radio tube. The reaction velocity corresponds to the tube current, the concentration (chemical potential) of the reactant corresponds to the plate voltage, and the concentration of the modifier corresponds to the voltage on a control grid. Various enzymic "circuits"in a living cell are analogous in function to such familiar electronic circuits as constant-voltage regulators, voltage amplifiers, current or output amplifiers, and so on.

Lecture V. Biological Macromolecules

Proteins

The operational specificity of living systems depends on proteins. Since nearly every property of a living cell–dynamic complexity, stability, regulators and so on–depends on a very high degree of operational specificity, proteins are responsible for the properties and effective functioning of organisms.

As we saw earlier, proteins are almost incredibly complex in function and behavior. It is difficult to believe that such sophisticated mechanisms can be constructed from 20 relatively simple organic compounds (amino acids), all connected by the same chemical linkage (the peptide bond). Some enzymes or other functional proteins contain chemically bound sugar or lipids that are necessary for function, but even in such cases, there seems no doubt that the primary structure on which function is based is supplied by the protein.

The number of possible sequences of amino acid residues in a protein is incomprehensibly large; thus, enzymes have been selected from an essentially infinite number of potential protein molecules. About 300 amino acid residues may be taken as the lower limit of length observed for functional polypeptides. There are 20^{300} possible linear arrangements of 300 amino acids of 20 kinds. This number , equivalent to 10^{400}, is much larger than any physically meaningful number, including estimates of the number of protons and neutrons in the known universe. The number of possibilities increases exponentially with length of the chain, of course, and the polypeptide chains in most enzymes are considerably longer than 300 residues.

The functional properties of proteins must depend on the steric relationships of functional groups; that is, on how the residues are arranged in 3-dimensional space. All of our present evidence indicates that this 3-dimensional arrangement depends in turn only on the primary sequence of amino acids; there seem not to be any shaping or molding steps in protein synthesis. Once the amino acid sequence is produced by mechanisms that we will discuss later, the chain apparently assumes its functional shape spontaneously. Although these shapes are very complex, each molecule of a given protein finds the same final configuration.

Various types of chemical attractions are responsible for stability of the 3-dimensional conformations of proteins. Parts of many polypeptide chains are arranged in the α-helix, in which each amino acid is hydrogen-bonded to the third residue along the cahin. Such H-bonding is important also in stabilizing other arrangements in space besides the helix. The properties of the side chains (the groups attached to the α-carbon atoms of the amino acids) are also involved. As especially important type of interaction between side chains is *hydrophobic interaction*, an example of polar/nonpolar (or oil/water) mutual exclusion. Regions of a peptide chain containing mainly hydrocarbon side chains tend to come together in such a way as to exclude water. Indeed, the centers of many proteins are made up exclusively of hydrophobic residues, and there is very little if any internal water.

Many enzymes are made up of subunits. (Each subunit is a separate polypeptide chain; thus, in classical terms it is a molecule and the enzyme is an aggregate of molecules. However, because of its functionality, the assembled enzyme is usually referred to as a molecule). The subunits may be identical or different. Hemoglobin, for example, contains 4 subunits, 2 each of two slightly different types. Regulatory enzymes, especially, are usually made up of subunits, and combinations of many different types are known, ranging from 2 to 12 identical subunits, and from 1 to 6 each of two types of subunits. The subunits are arranged in a highly specific way in the functional enzyme, but no covalent bonding is involved.

Much information about the types of attraction that are important in stabilizing protein structures has come from the study of *denaturation*—the loss of structure. In denaturing, a protein loses its biological activity, and changes in such chemical properties as which functional groups are available for reaction with analytical reagents, as well as in physical properties such as solubility. No covalent bonds are broken in denaturation—the change is from an ordered and specific arrangement of polypeptide chains to a random and disorganized one. This illustrates again the generalization that iological function, and thus, life itself, depends primarily on ordered structure. Denaturation, when carried out under controlled conditions, is in some cases reversible.

Nucleic acids

Like proteins, nucleic acids are built up from a small number of building blocks, but in this case the number of building blocks is even smaller—5 nitrogen-containing cyclic compounds (the purine and pyrimidine bases), 2 sugars (ribose and 2-deoxyribose), and phosphate. The repeating unit of the nucleic acid structure, the nucleotide, contains one base, one sugar molecule, and one phosphate.

The two types of nucleic acid, deoxyribonucleic acid or DNA and ribonucleic acid or RNA, differ very slightly in composition and primary structure, but greatly in function. In RNA the sugar is ribose and the bases are adenine, guanine, uracil, and cytosine. In DNA the sugar, 2-deoxyribose, differs from ribose only in having one atom less of oxygen, and uracil is replaced by 5-methyl uracil, which is named thymine. RNA molecules are very large by ordinary standards, with molecular weights up to a few million. Most DNA molecules, however, are much larger still, containing millions of nucleotides and having molecular weights in the billions.

The double helical structure of DNA, and the A-T and G-C base pairing on which it depends, must be "familiar" to any high school student whose reading has gone beyond comic books. Two polynucleotide chains can coil together, taking approximately the positions in space of two strands of a 3-stranded rope, if the order of their vases is exactly complementary. This means that, reading from chemically opposite ends of the two chains, there must be a G in one corresponding to every C in the other, and a T in one corresponding to every A in the other. The chemical basis for this double helix is that A and T contain functional groups allowing the formation of two hydrogen bonds; similarly, G and C can form three hydrogen bonds. It is extremely important that the distance across a base pair (between the two points of deoxyribose attachment) is almost exactly the same for G-C and A-T pairs. Thus, the distance between the —sugar—P—sugar—P—sugar—P backbones of the polynucleotide chains is constant, and a regular and ordered structure is possible.

As in the case of proteins, nucleic acids may be denatured, losing their biological function and changing greatly in physical properties. No covalent bonds are broken, but the double helical structure is lost by opening of the hydrogen bonds and dissociation of the base pairs that stabilized the helix. Because many kinds of attractive forces are involved in maintaining the structure of a protein, its denaturation has no specific characteristic temperature. In DNA, only the base interactions are disrupted. Since they are all nearly identical, the denaturation of DNA is a sharp function of temperature, almost like a phase change. For this reason it is usually called "melting," although there is no real resemblance to actual melting. The great specificity of attraction between polynucleotide chains with complementary sequences is demonstrated by the fact that denaturation of pieces of DNA with molecular weights in the hundreds of thousands or millions is reversible; during very slow cooling the dissociated pairs find each other and reform a double helix.

The main biological function of nucleic acids is information storage and transfer, and the sequence of bases in DNA is the primary determinant of the amino acid sequences of proteins, and ence of all the structural and functional order of organisms.

Lecture VI. Replication of Nucleic Acid and Synthesis of Protein

The cell's DNA is its library of master plans, containing all of the information needed for synthesis of the cell's components. Thus, the DNA must be processed in two ways: it must be copied, so that new cells, each with a full library of information, can be made, and portions of it must be transcribed, giving the blueprints for production of individual proteins.

Work of the last two decades on these processes has been widely publicized, and by now everyone must know that specific A-T and G-C base pairing is the basis for copying of DNA and also for the production of messenger RNA, which carries the recipes for making protein. It is also general knowledge that these recipes are written in a language in which each of the 20 amino acids is specified by one or more three-nucleotide "words."

First, it should be emphasized that, contrary to statements in some textbooks, there are no self-replicating molecules in biology (or, presumably, anywhere else). The replication of DNA, like all other biological processes, depends on the catalytic action of specific enzymes. Little is known for certain as yet of the details of this process. Several enzyme systems capable of copying DNA have been studied, but the physiological function of at least some of them seems to be repair of damaged DNA, rather than synthesis of new DNA. It is well established that nucleoside triphosphates are used in synthesis, with the terminal two phosphates being split off as inorganic pyrophosphate when the nucleotide (nucleoside monophosphate) is added to the growing polynucleotide chain.

In bacteria, where the DNA is in the form of a single circle naked in the cytoplasm, it has been possible to establish that the copying mechanism moves linearly along the DNA chain, with two DNA chains trailing behind. The DNA of more complex cells is in chromosomes in the nucleus. Chromosomes contain more protein than DNA, and the DNA cannot be directly visualized. There are several to many chromosomes in a nucleus, and little is known of the physical arrangement of DNA in each. Thus, our belief that the copying of DNA in nuclei is similar to that in bacteria rests mainly on the fact that this seems reasonable by analogy and there is no conflicting evidence.

Since the amount of DNA in cells of a given organism is constant, it is clear that DNA is copied exactly once per cell division. In an adult higher animal like ourselves, there is relatively little cell division, and hence relatively little DNA replication, in most tissues. This does not mean, however, that our DNA is inactive; the function of DNA, as far as an individual cell is concerned, is not to be copied, but to supply the information for protein synthesis.

An enzyme system, DNA-directed RNA sythase, catalyzes the production of messenger RNA molecules that are complementary to short sections of one of the DNA strands. Surprisingly, the strand used is not always the same; that is, the information for production of messenger RNA may be in strand A in one region of the DNA and in strand B in another region. We do not yet understand how the enzyme system is prevented from copying the wrong strand, or how it finds the correct starting point. Each m-RNA molecule contains information for the synthesis of at least one, and often several, proteins.

Protein synthesis

Protein synthesis requires ribosomes, transfer RNA's, (t-RNA's), amino acid activating enzymes, and several other protein factors.

Ribosomes are the particles on or in which actual protein synthesis (the formation of new peptide bonds) occurs. The ribosome moves along the m-RNA molecule, synthesizing the polypeptide chain specified by the nucleotide sequence of the m–RNA. Ribosomes of bacteria have a sedimentation coefficient of 70S, and are made up of two parts of unequal size, 50S and 30S. These parts apparently are combined only during actual synthesis of a protein; the 30S particle first binds the m-RNA, and then the 50S particle adds. Ribosomes of nucleated cells are larger, having a sedimentation coefficient of 80S (particle weight of about 4×10^6), and contain subunits of about 60S and 40S. In both cases, each type of subunit contains both protein and RNA, which is called r-RNA (for ribosomal RNA). There are several r-RNA molecules of different kinds in each ribosome.

t-RNA

Each transfer RNA molecule contains the *anti-codon* triplet complementary to the m-RNA codon for a specific amino acid. t-RNA serves as an adapter, carrying a specific amino acid to the point of peptide chain elongation when that amino acid is specified by the code of the m-RNA that is being read. There is some A-U and G-C base pairing in t-RNAs, and the resulting configuration is something like a clover leaf or the playing-card symbol for clubs. The amino acid is attached at one end of this structure (the stem) and the anticodon is at the other end (on the middle leaflet). Although t-RNA molecules of different types differ slightly in molecular weight (they contain from 70 to 95 nucleotides), they appear all to be the same length from the anticodon to the point of amino acid attachment. This uniformity of length seems to be essential to the function of t-RNA, which is to position the right amino acid at the right place at the right time for incorporation into protein.

The *amino acid activating enzymes* supply the operational specificity of the protein-synthesizing system. Put in another way, they carry out translation form nucleotide language to amino acid language. Each amino acid activating enzyme must recognize and bind one kind of amino acid with very high specificity, recognize and bind an appropriate t-RNA molecule, and catalyze the attachment of the amino acid to the stem end of the t-RNA. One molecule of ATP is used in this process.

The synthesis of protein in bacteria may be briefly summarized as follows: A 30S ribosome subunit binds to an initiation point on a molecule of m-RNA. A t-RNA carrying formyl-methionine is attached (all bacterial proteins apparently begin with formyl-methionine when they are synthesized, but this end residue is often hydrolyzed off before the protein begins its functional life). A 50S particle attaches. Molecules of "charged" t-RNA (molecules bearing attached amino acid residues) approach the synthetic site, presumably by interaction between specific groups on the ribosome and groups on one or both of the side leaflets of the t-RNA, but a r-RNA molecule can fit fully into the site only if its anticodon is complementary to the next triplet codon of the m-RNA. When a properly-fitting t-RNA is attached, its amino acid residue is automatically positioned for reaction with the formyl-methionine already in palce. Each subsequent amino acid residue is added in the same way. In bacteria, about 10 amino acids can be added per second. A typical mammalian rate may be about 1 per second.

The actual bond-forming step in protein synthesis is displacement of the t-RNA to which the peptide chain is attached by the free amino group of the residue to be incorporated. Thus, the growing chain is transferred from the t-RNA to which it had been bound and attached to the new amino acid (which is still bound, of course, to its own t-RNA).

The t-RNA from which the polypeptide chain was transferred then dissociates from the ribosome and is recharged with the appropriate amino acid by the corresponding specific amino acid activating enzyme. The ribosome somehow moves along the m-RNA chain the distance of 3 nucleotides, placing the t-RNA to which the growing peptide is attached in the donor or peptidyl site and positioning the next nucleotide triplet in the recognition site. When the corresponding charged t-RNA finds its way to this site, the process is repeated.

As the ribosome moves down the m-RNA molecule, the initiation site is uncovered, and another ribosome may attach. A m-RNA molecule may be read simultaneously by many ribosomes. The resulting structure of one m-RNA with the associated ribosomes, which in electron micrographs resembles beads in a string, is called a *polyribosome*, or *polysome*.

The end of the specification for each protein is indicated by a termination codon—a triplet that does not code for any amino acid, but causes the polypeptide chain to be released into the cytoplasm by hydrolysis from the t-RNA that had carried the last amino acid residue. Additional protein factors involved in initiation and termination have been discovered, and it is clear that much remains to be learned about the details of protein synthesis.

Control of protein synthesis

Each of the many hundred, or few thousand, enzymes in a cell must be maintained at an appropriate level; thus, there clearly is some overall regulatory system by which the rate of synthesis of each enzyme is kept in balance with the rate at which it is wearing out or being destroyed. (Most proteins are constantly being replaced, but their turnover rates vary considerably). In addition, cells of higher organisms have a related and more complex problem. Each cell of our bodies contains all of the information (all of the DNA) needed to specify everything about us, but each individual cell uses only a very small amount of that information. It is obvious that the brain does not make muscle fibers, the pancreas does not make lens protein, the retina does not make pancreatic enzymes, and so on. It is less obvious, but true, that even the "same" enzyme from different tissues of the same animal (that is, enzymes that catalyze the same reaction) are frequently found to be different in amino acid sequence. Somehow each cell at any instant makes only the proteins that are appropriate for that cell at that stage in its development, and at that stage in the development of the whole organism. The question of how this comes about is the molecular aspect of the enormous problem of biological differentiation. There can be little doubt that the study of differentiation will be one of the most active and most important areas of biology and biochemistry during the next scientific generation. At present, we have much information as to some of the things that happen, but very little understanding of how they happen.

One special aspect of the problem of regulation of protein synthesis has been much studied and is beginning to be understood in vague outline. Bacteria, being single-celled, are not differentiated in the same sense as higher organisms. They can, however, adjust the production of some of their enzymes to fit their immediate needs. This control is called repression and induction (or derepression.) There are two main types, with many modifications in individual cases.

Biosynthetic repression

The end product of a biosynthetic sequence (such as an amino acid), in addition to exerting kinetic control on the first enzyme in the sequence as we have seen, often *represses* the synthesis of all of the enzymes in the sequence. That is, the rate of synthesis of all of these enzymes is greatly decreased when they are not needed. In some cases, all of the enzymes of a synthetic sequence are specified by a single large m-RNA molecule, and repression of all of them apparently results from inhibition of production of that m-RNA. Other cases are more complex, and involve several kinds of m-RNA.

Induction and catabolite repression

Bacteria typically contain genetic information in their DNA for the synthesis of enzymes that allow the use of a wide variety of compounds as sources of carbon and energy. Most of these enzymes are not made under normal conditions. Their production is controlled by a rather complex regulatory system that senses, firstly, the need for an alternate source of energy, and secondly, what source, if any, is available.

Glucose is the best energy source for most species. When adequate glucose is present, the enzymes for metabolism of unusual or secondary energy sources are not made. These enzymes are said to be repressed. Because glucose is so effective, such repression was at first termed glucose repression, but it is now known that varying degrees of repression can be caused by other substrates that support rapid growth, and the phenomenon is now termed *catabolite repression.* If the supply of glucose is exhausted, the resulting energy shortage, in some way not yet understood, causes the production of 3′, 5′-cyclic AMP (an isomer of ordinary AMP). Each inducible/repressible enzyme can be made only if both cyclic AMP and an inducer, specific for each, is present. The inducer is typically the alternative carbon source itself. Thus β-galactosidase, the first enzyme needed for utilization of lactose, is not made when both glucose and lactose are present because the level of cyclic AMP is too low; it is not made if both are absent because induction by lactose (or a closely related molecule) is necessary. It is, of course, not made when glucose is present and lactose absent. It is made only when glucose is absent and lactose present, and this is precisely the only time that it is needed.

There are many such inducible and repressible enzymes. Although not all of them have been studied in detail, it seems likely at present that all are repressed when the level of cyclic AMP is low, whether or not the corresponding substrate is present, and that when the level of cyclic AMP rises each can be individually induced, but only by the presence of the substrate. This kind of control evidently allows the cell to economize in the very expensive process of protein synthesis by not making unneeded enzymes. There is good evidence that, in at least some cases, the inducer is recognized by a specific protein (called, unfortunately, the repressor protein). This protein interacts with a specific point on the cell's DNA to prevent synthesis of the m-RNA corresponding to the inducible enzyme, but when it binds the inducing substrate it changes conformation so as not to interact with DNA; m-RNA and enzyme can then be made.

Many mammalian enzymes, especially in the liver, are similarly synthesized at rates depending on metabolic needs. It seems likely that similar regulatory mechanisms are involved, although there is as yet little or no proof of this. We do not yet know whether the regulation of protein synthesis that underlies differentiation is at all similar to repression/induction.

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